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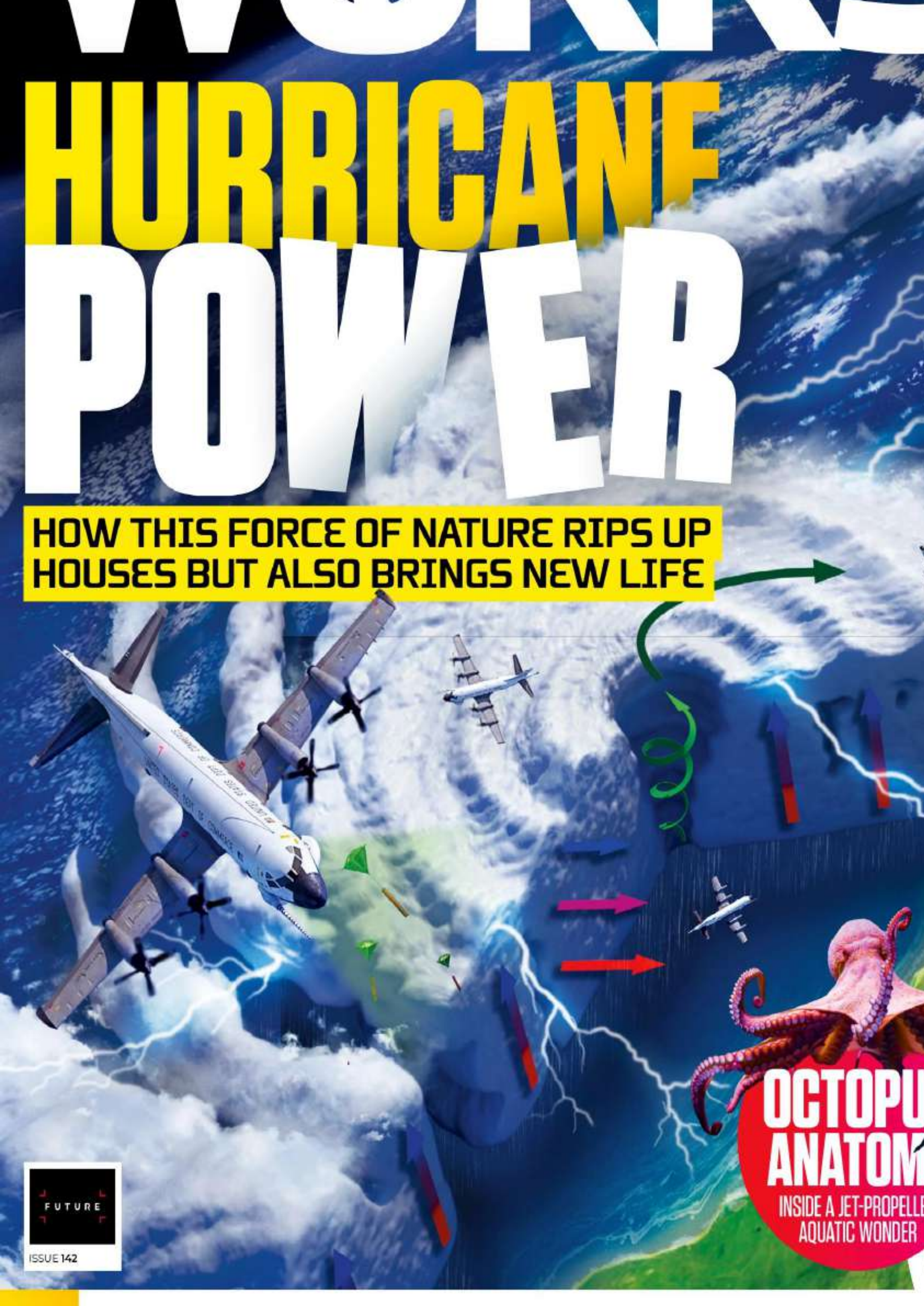

RISE OF AUSTRALIA'S WEIRD MAMMALS

WHY WINGSUITS ARE GREAT FOR GLIDING

DELICIOUS SECRETS OF A CHOCOLATE FACTORY

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FUTURE
ISSUE 142

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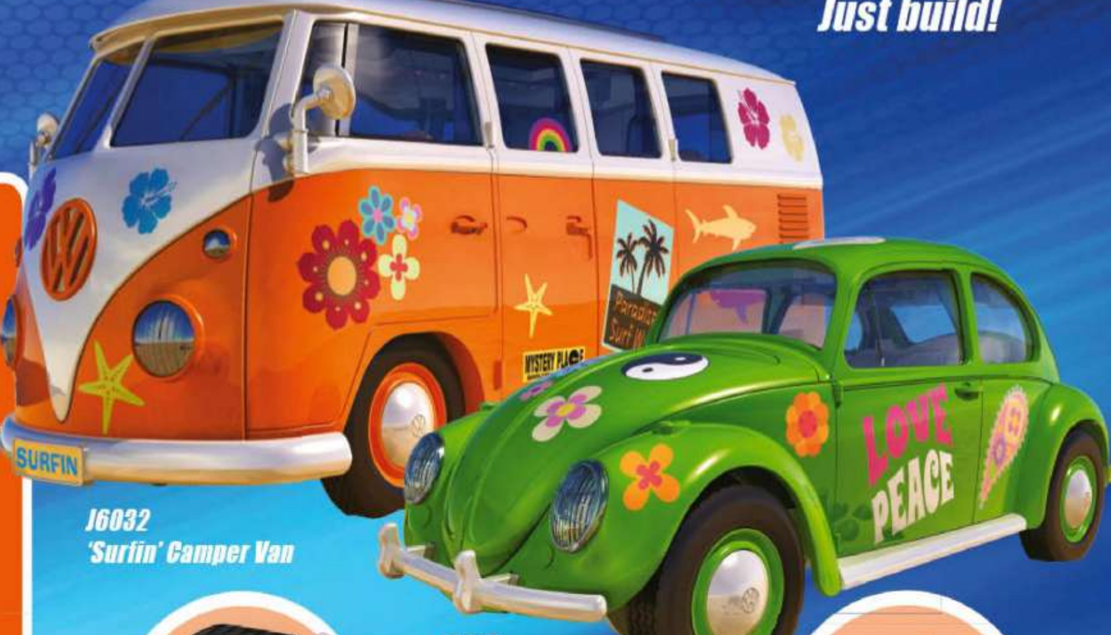
	m	m
4	4.07	1.5
m	kg	km/h
1.54	725	115
L/100km	0-100km/h	kW
7.5	23s	40

1.2L Flat 4

	m	m
4	4.2	1.94
m	kg	km/h
1.7	1500KG	100
L/100km	0-100km/h	kW
9	40s	38kW

1.5L Flat 4



J6032
'Surfin' Camper Van

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Beetle

Build and Decorate Two Iconic Models

In a trend that started on the California coast, Camper Vans customized with vinyls, bumperstickers or freehand painting have become the number one iconic mode of transport for the world-wide surfing community. The origins of this vehicle started with the 'Type 2', affectionately known as the 'Camper' in the UK, and was the second car model to be introduced by Volkswagen in 1950. The first prototype of the Camper was revealed to the world in November 1949 and the very same prototype can still be seen today at the Volkswagen AutoMuseum in Wolfsburg, Germany. VW's first release, the Beetle, was named 'Type 1' resulting in the Camper being predictably named 'Type 2.' Depending on body style the Type 2 was officially known as the Transporter, Kombi or Microbus.

Another trend that began on the coast of California, second hand VW's beetles (Bugs!) became extremely popular with the emerging counter culture of the 1960's. In a movement that promoted freedom of expression, the charming, little VW Bug became everyones' favourite canvas. The Volkswagen Beetle remained in production throughout the whole period and entered the record books as the best selling single-model car of all time on February 17th 1972 when production reached 15,007,034 units, beating the previous record of the Ford Model T. When production finally ceased on July 30th 2003, Volkswagen had produced a total 21,529,464 and it's unlikely this record will be broken again as cars now rarely remain in production longer than 10 years.

Both of these vehicles have become true icons on roads all over the world! You can create your own versions at home with these Airfix QuickBuild kits. Both models come with an array of colourful stickers to help you customise your own design. You can recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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HURRICANE POWER

"It can't be denied that they have the power to ruin lives"

Hurricane power, page 20

Meet the team...

Nikole
Production Editor
Broken satellites and other space junk are cluttering up the atmosphere. Find out what weird things are up there on page 64.

Scott
Staff Writer
The next generation of gaming consoles are coming this year. Get a glimpse inside the PS5 and Xbox Series X on page 36.

Baljeet
Research Editor
From bottles and bowls to stained-glass windows, learn how glass is made and shaped for a range of uses on page 50.

Duncan
Senior Art Editor
On page 44, see how mummification was performed and where mummies have been discovered across the world.

Ailsa
Staff Writer
After millions of years of isolation, Australia has produced unique animals. Discover these marsupials on page 28.

From the comfort of our homes, behind a television set, most of us are awestruck and thrilled to watch the power of a hurricane as it unfurls. For some people though, it's their job to fly high above the swirling storm clouds and actually drop into the eye of the storm to monitor the activity inside. In this issue of **How It Works** magazine, see how a few scattered rain clouds on one side of the world can turn into a raging maelstrom on the other, tearing up trees and flooding cities. Learn how pilots and planes are equipped to monitor these wild forces of nature and discover the biggest, most powerful hurricanes of all time. Enjoy the issue!

Ben Editor

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AR ZONE!

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When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

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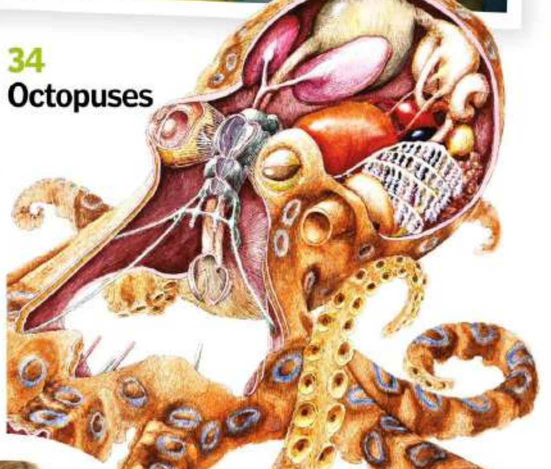

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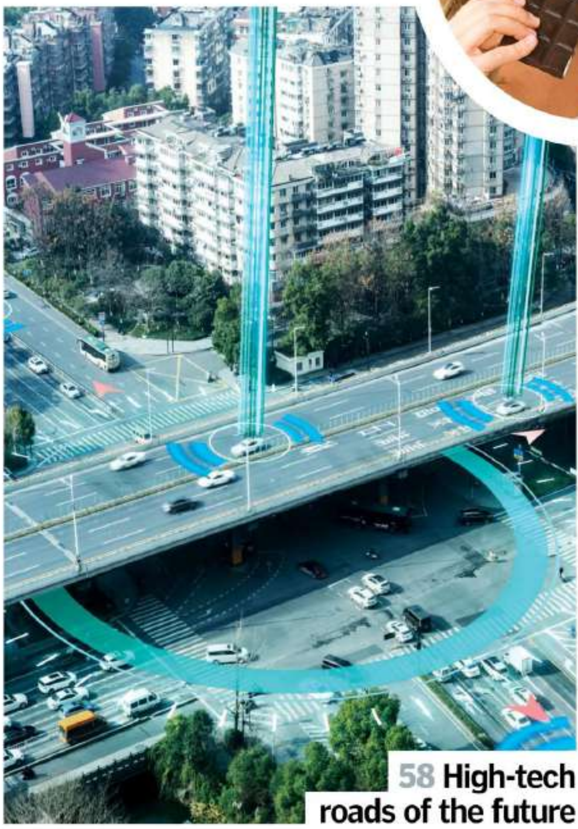

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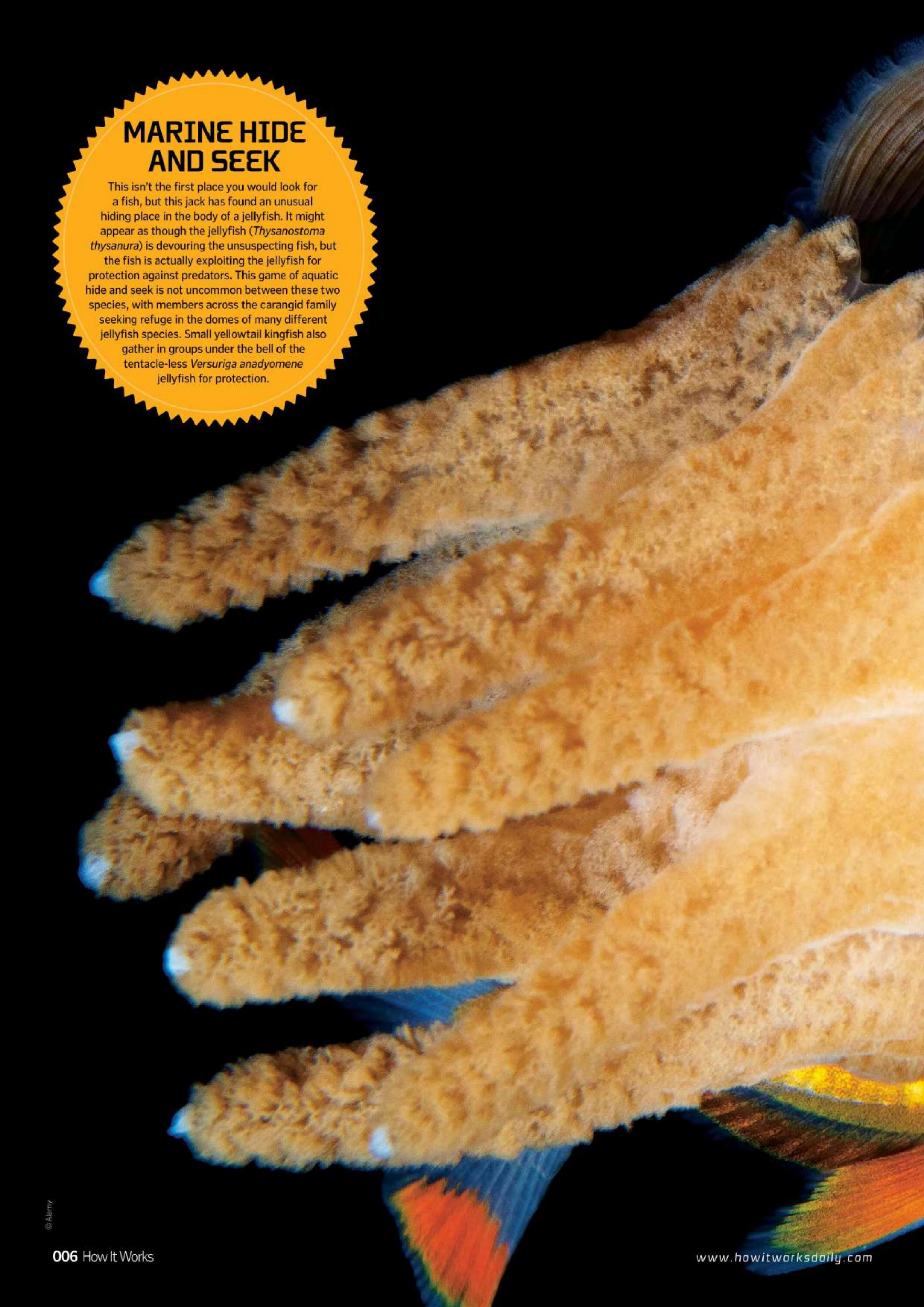

MARINE HIDE AND SEEK

This isn't the first place you would look for a fish, but this jack has found an unusual hiding place in the body of a jellyfish. It might appear as though the jellyfish (*Thysanostoma thysanura*) is devouring the unsuspecting fish, but the fish is actually exploiting the jellyfish for protection against predators. This game of aquatic hide and seek is not uncommon between these two species, with members across the carangid family seeking refuge in the domes of many different jellyfish species. Small yellowtail kingfish also gather in groups under the bell of the tentacle-less *Versuriga anadyomene* jellyfish for protection.

© Alamy

INSIDE A DEAD STAR

Around 6,500 light years away in the constellation of Taurus are the cosmic remains of an exploded star known as the Crab Nebula. Back in 2018 NASA created this image from a data collaboration between the Chandra X-Ray Observatory (blue and white), the Hubble Space Telescope (purple) and the Spitzer Space Telescope (pink). It shows that at the heart of the nebula lies a highly magnetised, spinning neutron star known as a pulsar, emitting powerful electromagnetic radiation from its magnetic poles. The Crab Pulsar is just 19 kilometres wide, spins 30 times a second and can produce 10 quadrillion electron volts.

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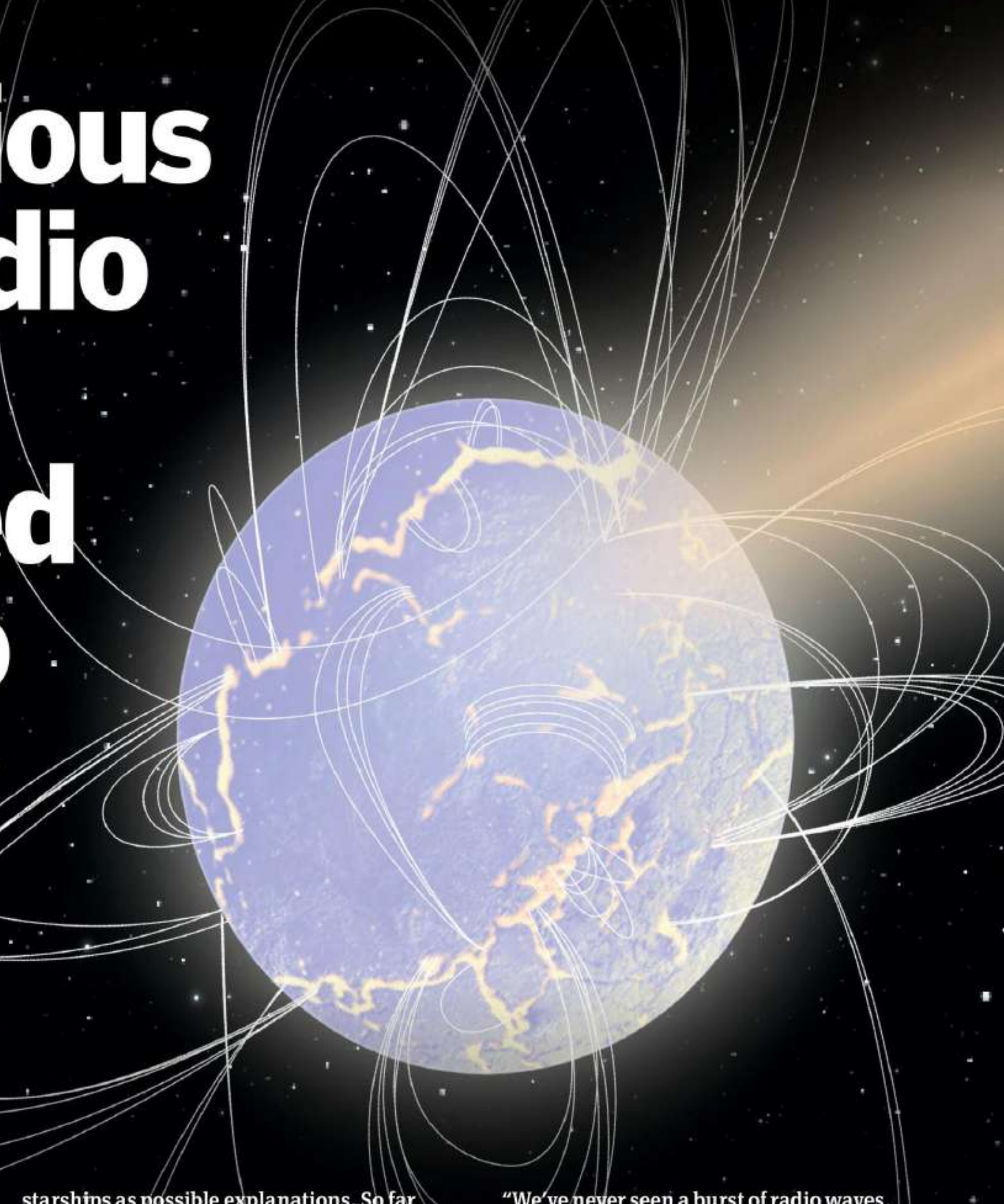
SPACE

Mysterious 'fast radio burst' detected close to Earth

Words by **Brandon Specktor**



30,000 years ago a dead star on the other side of the Milky Way belched out a powerful mixture of radio and X-ray energy. On 28 April 2020 that belch swept over Earth, triggering alarms at observatories around the world. The signal was there and gone in half a second, but that's all scientists needed to confirm they had detected something remarkable: the first-ever 'fast radio burst' (FRB) to emanate from a known star within the Milky Way.

Since their discovery in 2007, FRBs have puzzled scientists. The bursts of powerful radio waves last only a few milliseconds at most, but generate more energy in that time than our Sun does in a century. Scientists have yet to pin down what causes these blasts, but they've proposed everything from colliding black holes to the pulse of alien starships as possible explanations. So far every known FRB has originated from another galaxy, hundreds of millions of light years away.

This FRB is different. Telescope observations suggest that the burst came from a known neutron star – the fast-spinning, compact core of a dead star which packs a Sun's worth of mass into a city-sized ball – about 30,000 light years from Earth in the constellation Vulpecula. The stellar remnant fits into an even stranger class of star called a magnetar, named for its incredibly powerful magnetic field, which is capable of spitting out intense amounts of energy long after the star itself has died. It now seems that magnetars are almost certainly the source of at least some of the universe's many mysterious FRBs.

"We've never seen a burst of radio waves, resembling a fast radio burst, from a magnetar before," said Sandro Mereghetti of the National Institute for Astrophysics in Milan. "This is the first-ever observational connection between magnetars and fast radio bursts."

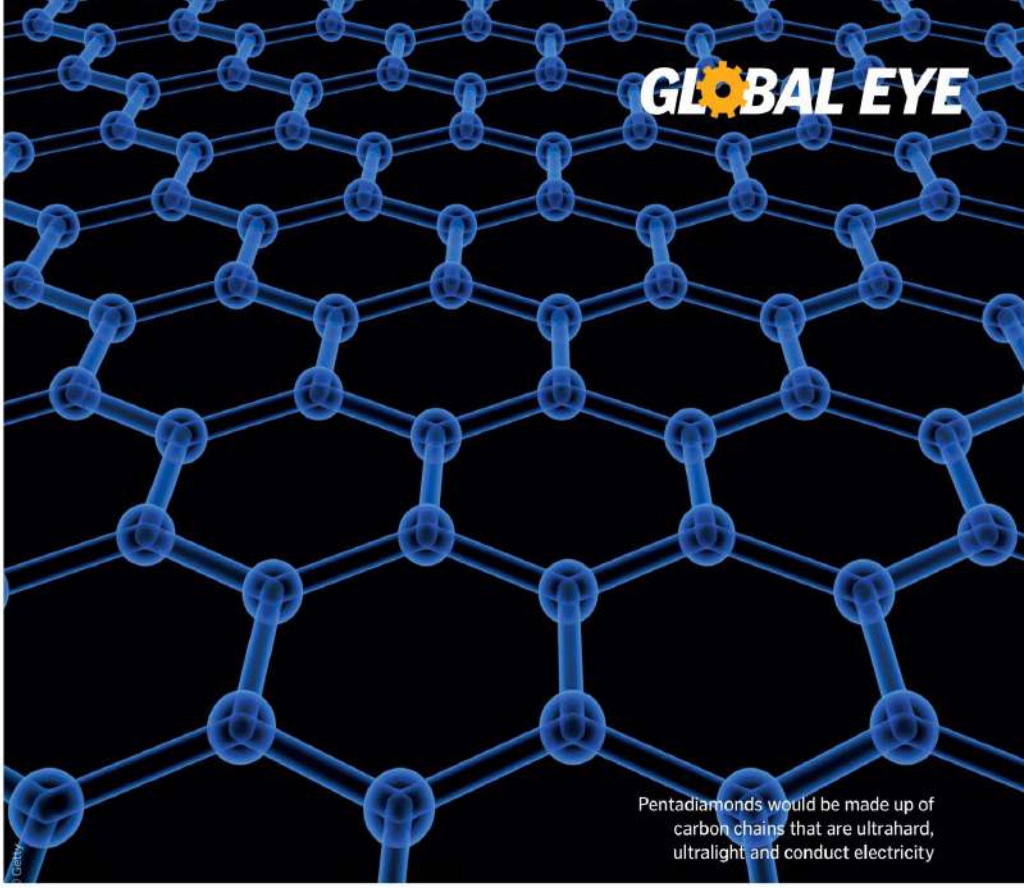
The magnetar, named SGR 1935+2154, was discovered in 2014 when scientists saw it emitting powerful bursts of gamma rays and X-rays at random intervals. After quieting down for a while, the dead star woke up with a powerful X-ray blast in late April. Mereghetti and his colleagues detected this burst with the European Space Agency's (ESA) Integral satellite, designed to capture the most energetic phenomena in the universe. At the same time a radio telescope in the mountains of British Columbia, Canada,

© ESA

Artist's impression of a magnetar launching a burst of X-ray and radio waves across the galaxy

detected a blast of radio waves coming from the same source. Radio telescopes in California and Utah confirmed the FRB detection the next day. A simultaneous blast of radio waves and X-rays has never been detected from a magnetar before, strongly pointing to these stellar remnants as plausible sources of FRBs.

Crucially, ESA scientist Erik Kuulkers added, this finding was only possible because multiple telescopes on Earth and in orbit were able to catch the burst simultaneously, and in many wavelengths across the electromagnetic spectrum. Further collaboration between institutions is necessary to further "bring the origin of these mysterious phenomena into focus," Kuulkers said.



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Pentadiamonds would be made up of carbon chains that are ultrahard, ultralight and conduct electricity

TECH

'Pentadiamonds' could reshape material engineering

Words by **Adam Mann**

What's harder than a diamond, a third lighter and could zip with electricity? A pentadiamond. A crystalline arrangement of carbon atoms that is made up mostly of pentagons. These don't exist yet – they've only been created in computer simulations – but if one can be made, it could have a number of useful properties.

Carbon is one of the most versatile elements on the periodic table. Since each carbon atom can bond with up to four others, it is able to form intricate assemblies with different properties, such as ultra-hard diamond, semiconducting graphene and rope-like nanotubes.

Novel arrangements, or allotropes of carbon are being discovered all the time. As many as 1,000 different types are currently known. The search for additional allotropes is like "playing [with] LEGO blocks to create materials with fascinating shapes and structures," said Susumu Okada, a condensed matter physicist at the University of Tsukuba in Japan.

Using state-of-the-art computer modelling, Okada and his colleagues decided to bring together two molecules – spiro[4.4]nona-2,7-diene and [5.5.5.5]fenestratetraene – each of which contained a pentagonal ring of carbon atoms, to see if they might generate a potentially useful material. The simulations produced a carbon arrangement looking a bit like a typical football with several smaller footballs glued all around its exterior. The computer model was able to show that this pentadiamond, if it were synthesised in real life, would have some interesting properties.

Along with being stiffer than a standard diamond, which is one of the hardest substances known, pentadiamond would be slightly porous and could conduct electricity like the semiconductors used in electronic devices if chemical impurities were added.

If you held a pentadiamond in your hand it would likely feel lighter than a similar-sized diamond, though it wouldn't be clear – rather a greyish colour like graphite. Because of its porous nature pentadiamond might be useful for storing gas, Okada said. Its lightness and hardness could make it useful for building the bodies of race cars, he added.

Purusottam Jena, a physicist at Virginia Commonwealth University, who was not involved in the work but has discovered other carbon allotropes, said the material is potentially quite exciting. "However, it needs to be experimentally synthesised," he added, and until then remains strictly theoretical.

ANIMALS

Fungus turns cicadas into zombie slaves

Words by **Mindy Weisberger**

Male cicadas infected by a particularly gruesome parasitic fungus become zombies with an undercover mission: they broadcast a female's mate-seeking message to other male cicadas, luring their unsuspecting victims to join the zombie cicada horde.

Researchers recently discovered this unusual twist to the cicada's already horrific zombification story. As the parasitic fungus, called *Massospora cicadina*, eats away at a cicada's abdomen, replacing it with a mass of yellow spores, the fungus also compels males to flick their wings in movements that are typically performed by females to attract mates. Healthy males that hurry over for female company then try to mate with the infected male, which passes along the *Massospora* infection. This and other new discoveries are helping scientists to piece together how *Massospora* turns cicadas into mind-controlled zombies.

This zombie-host relationship can be challenging to observe. Though the fungus can affect cicadas that emerge annually, many of its cicada hosts are in the Magicicada genus, also known as periodical cicadas. These black-bodied, red-eyed cicadas spend 13 to 17 years – depending on the species – underground as immature nymphs. Luckily for the scientists who study periodical cicadas, local populations known as broods that follow this cycle emerge during different years in different locations.

Once the cicadas emerge and moult their exoskeletons they enjoy just a few weeks of life on the surface as adults, mating and laying eggs before dying. However, for cicadas infected by *Massospora*, life takes an ugly turn. About a week after being infected, fungal spores devour the cicada's abdomen and its body disintegrates, but the insect doesn't die. It continues to fly around and disperse the zombifying spores far and wide in a process known as active host transmission (AHT), in which a parasite manipulates its living host.

One form of this manipulation compels infected males to imitate female behaviours, moving their wings to lure and infect even more cicadas. This is the only known example of AHT in which the pathogen behaves at least in part as a sexually transmitted disease, as transmission sometimes happens when males attempt to copulate with infected males.

At least some of the chemical cues responsible for the cicadas' unnatural behaviour are psychoactive; one of these is psilocybin, which is also found in hallucinogenic mushrooms. But though scientists have identified some of the chemicals in *Massospora* fungus, the spores' mechanisms for controlling their cicada host have yet to be explained.

"These discoveries are not only super cool, but also have a lot of potential in helping us understand insects better, and perhaps learn better ways to control pest species using fungi that manipulate host behaviours," said Angie Macias, a West Virginia University doctoral candidate. "It is almost certain that there are undiscovered *Massospora* species, never mind the other AHT fungi, and each of these will have developed its own intimate connection with its host's biology."

A parasitic fungus manipulates male cicadas into flicking their wings like females to tempt and infect other males

© Getty

The site of the methane leak was stained with a white mat of hungry microbes

© Andrew Thurber, Oregon State University

PLANET EARTH

First underwater methane leak discovered near Antarctica

Words by **Brandon Specktor**

Just below the freezing Antarctic ice shelves, researchers have discovered a gas leak that could change the region's climate destiny. For the first time scientists have detected an active leak of methane gas, a greenhouse gas with 25-times more climate-warming potential than carbon dioxide, in Antarctic waters. While underwater methane leaks have been detected previously all over the world, hungry microbes help keep that leakage in check by gobbling up the gas before too much can escape into the atmosphere. But that doesn't seem to be the case in Antarctica.

The researchers found that methane-eating microbes took roughly five years to respond to the Antarctic leak, and even then they did not consume the gas completely. The underwater leak almost certainly sent methane gas seeping into the atmosphere in those five years, a phenomenon that current climate models do not account for when predicting the extent of future atmospheric warming.

The recent leak, located about ten metres deep in the Ross Sea, near Southern Antarctica's Ross Ice Shelf, was discovered by chance when civilian divers happened to swim by in 2011. The seabed showed telltale signs of a methane leak: white 'mats' of microorganisms that exist in a symbiotic relationship with methane-consuming microbes stretched out in a 70-metre line along the seabed.

A sediment analysis confirmed the obvious: methane was escaping from below the seabed. Five years later more microbes had appeared, but the methane continued to flow. Scientist Andrew Thurber called the discovery "incredibly concerning," as most climate models count on methane-eating bacteria to remove this underwater threat almost immediately. This slow microbial response, coupled with the leak's shallow depth, suggests that significant amounts of methane have been pouring into the atmosphere above the Ross Sea for years.

In big-picture terms, this is just one small leak, and it probably won't tip the climate scales in any significant way. But the waters around the southern continent may contain as much as 25 per cent of Earth's marine methane, and more leaks could be occurring right now without anyone knowing. Understanding how Antarctica's submarine greenhouse gas stores interact with the ocean and the atmosphere above could have huge implications for the accuracy of climate models.

STRANGE NEWS

Sly fox steals 100 shoes

Words by Mindy Weisberger

In Berlin a local fox was exposed as the culprit behind a string of shoe thefts. Last month Christian Meyer, a resident of Berlin's Zehlendorf neighbourhood, noticed that one of his new running shoes had disappeared from his porch, and he decided to investigate the theft.

Meyer quickly learned that he was not the thief's only victim, and a tip helped him catch the fox bandit red-handed with two blue flip-flops in its mouth. Days later Meyer spotted the fox again; he followed it into a thicket, where he crawled around for close to an hour. There he discovered the fox's secret stash of more than 100 shoes: trainers, clogs, sandals and slippers in a range of colours and sizes.

This isn't the first time that an urban fox has demonstrated an apparent shoe fetish. In August 2019 a fox in Melbourne, Australia, repeatedly visited a woman's porch and stole three boots over the course of a week.

A pair of foxes in Kyoto, Japan, pilfered more than 40 pairs of sandals in 2018 before the duo was apprehended in a stakeout involving five police officers. In 2009 in the small town of Föhren in western Germany, a female fox stole about 110 to 120 shoes in just one night. In 2013 a writer described waking up one morning in his London home to find that a fox had placed seven shoes in the middle of his lawn, "ranging in size from that of a toddler to an adult trainer."

Meanwhile, in Berlin, most of the fox's victims have been reunited with their shoes – except for Meyer, whose stolen trainer is still missing.

If you're missing a pair of shoes, they might have been taken by a red-tailed thief

© Getty

PLANET EARTH

Two Canadian ice caps have completely vanished from the Arctic

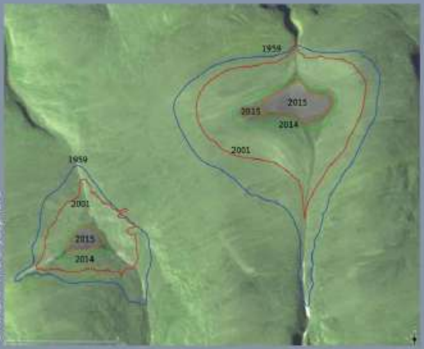
Words by **Brandon Specktor**

On frosty Ellesmere Island, where Arctic Canada butts up against the northwestern edge of Greenland, two once-enormous ice caps have completely vanished, new NASA imagery shows. However, it's no mystery where the caps, known as the St Patrick Bay ice caps, went.

Like many glacial features in the Arctic, which is warming at roughly twice the rate of the rest of the world, the caps were destroyed by climate change. Still, glaciologists who have studied these and other ice formations for decades are unnerved by just how quickly the caps disappeared from our warming planet.

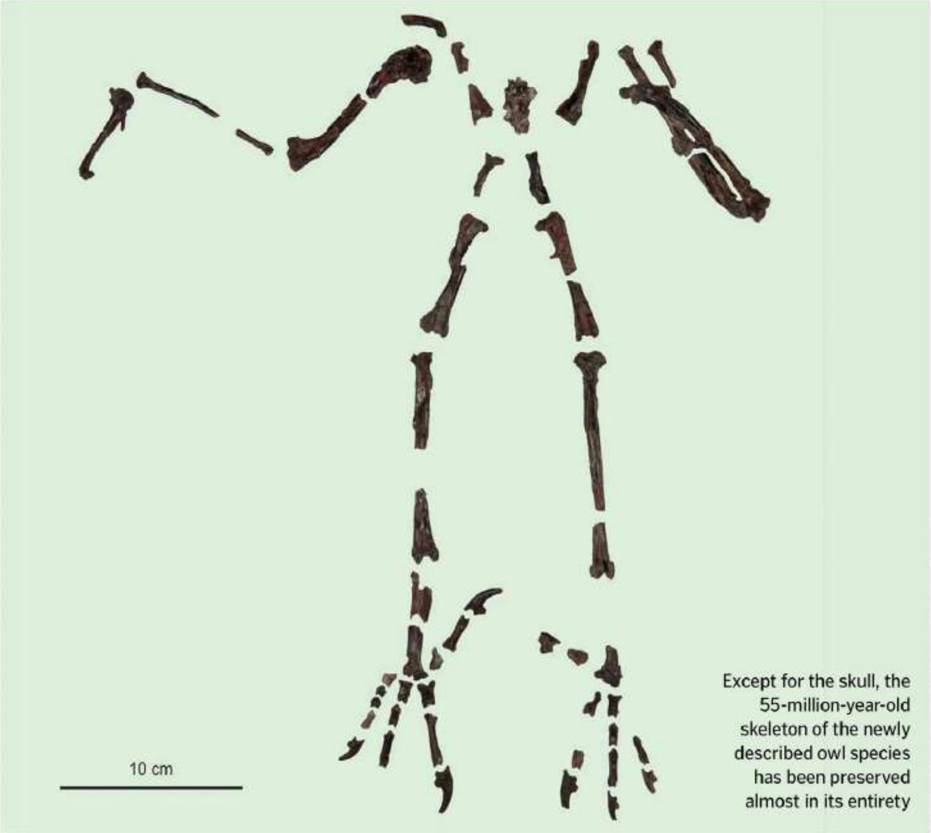
The St Patrick Bay ice caps sat about 800 metres above Ellesmere Island's Hazen Plateau in Nunavut, Canada, where they existed for hundreds of years. Researchers aren't sure how large the caps were at their maximum extent, but when a team investigated back in 1959 the caps covered about 7.5 square kilometres and three square kilometres respectively.

When researchers studied the caps again in 2017, the formations had shrunk to just five per cent of their former sizes. Researchers predicted that the caps would vanish completely within five years. Now here we are, with the caps gone two years ahead of schedule.



© NASA/The Cryosphere

This satellite image, captured in 2017, shows the rapid depletion of two ice caps in the Canadian Arctic. As of July 2020, both are gone



Except for the skull, the 55-million-year-old skeleton of the newly described owl species has been preserved almost in its entirety

© Senckenberg Research Institute and Nature Museum

ANIMALS

Ancient owl with 'murder feet' unearthed

Words by **Mindy Weisberger**

A 55-million-year-old owl fossil with so-called 'murder feet' has recently been described. Based on its preserved foot bones, this ancient avian predator likely hunted like a hawk, killing its prey with piercing talons, unlike its modern-day relatives that use their beaks to kill. The newfound skeleton, which represents a previously unknown owl genus and species, is the oldest near-complete owl fossil.

Though the fossil is missing its skull, nearly all the other bones in its body are intact and preserved in three dimensions. And this owl was a big one; at nearly 60 centimetres long it would have been about the size of a modern snowy owl (*Nyctea scandiaca*).

The fossil was discovered in 1990 in the Willwood Formation in northern Wyoming, in sediments deposited about 55 million years ago. Researchers named the newly described owl *Primoptynx poliotauros*, Primoptynx meaning 'first owl' in Latin.

Palaeontologists identify ancient owls by looking at the shapes of certain bones, among them the shoulder bone, the humerus in the wings and leg bones such as the tibiotarsus – a bone between the knee and the heel – and the tarsometatarsus – the bone between the heel and the toes – which are important for catching prey or perching. In the case of *Primoptynx*, however, the bones that captured the scientists' attention were in the owl's toes. The toes of modern owls are all about the same size. *Primoptynx*'s first and second toes were bigger than the others, so its feet most closely resemble those of predatory raptors such as hawks and eagles. This suggests that the extinct owl hunted as hawks do, targeting larger or more difficult-to-capture prey and then clutching and piercing their bodies in a lethal death grip with its feet. By comparison, owls typically stab prey to death with their sharp beaks.

When *Primoptynx* soared across Wyoming skies 55 million years ago, North America was populated by mammals such as primates, rodents and early relatives of deer and horses. The owl's impressive feet could likely grip something the size of a rabbit, but rabbits had yet to appear in the region. Prior to this discovery, the oldest owl fossils were bone fragments and a leg bone dating to around 60 million years ago.

Skin pigments could assist in the development of spacesuits for future missions to Mars

©NASA/JPL-Caltech

SPACE

Space travel sunblock could be made from skin pigments

Words by **Adam Mann**

Explorers on the Moon or Mars may one day shield themselves using creams containing a new bioengineered material called selenomelanin, created by enriching the natural pigment melanin with the metal selenium. Outside Earth's protective magnetic field, humans are exposed to many types of dangerous radiation. This includes damaging ultraviolet radiation, X-rays and gamma rays from the Sun, as well as superfast subatomic particles called galactic cosmic rays that originate outside our Solar System.

The invisible accumulation of DNA breakage caused by these space rays can lead to cancer, and in high doses radiation poisoning and death. Traditional countermeasures, such as lead or water shielding, tend to be heavy and greatly increase the cost of a space mission.

Enter melanin, a broad class of naturally occurring pigments found in animals, plants, fungi and bacteria. Some types of melanin provide humans with their wide range of skin, hair and eye hues and help protect us against the Sun's ultraviolet light.

Animal melanins are divided into two main forms, eumelanin and pheomelanin. Eumelanin is responsible for conferring black or dark brown colours like that of skin and hair, while pheomelanin contains the element sulphur and tends to be reddish or yellowish, and is found in red or auburn hair and in human lips. Pheomelanin also absorbs X-rays much more efficiently than eumelanin. Knowing this, researchers took some pheomelanin derived from red rooster feathers and tried to see if they could make it even more protective.

Instead of sulphur the researchers swapped in the element selenium, which sits just below sulphur on the periodic table of elements and is known to play a role in cancer prevention in organisms. By doing so they created selenomelanin, which has never before been seen in nature.

During lab experiments, skin cells treated with selenomelanin were able to shrug off doses of X-ray radiation that would be lethal to a human being. The selenomelanin was absorbed into the cells and formed tiny shields around the cells' nuclei, where DNA is stored. The cells took on a naturally brown or tanned colour when they absorbed selenomelanin. Additional tests demonstrated that engineered bacteria fed selenium could produce selenomelanin, meaning the substance could be manufactured in space. The material will need to be tested on human beings and in space to see if it confers the same protection.

The fact that it is lightweight and can be created from basic organic chemicals during a space mission makes it quite attractive. Selenomelanin could even be incorporated into clothing, such as the lining of a spacesuit, to confer continuous protection.

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HISTORY

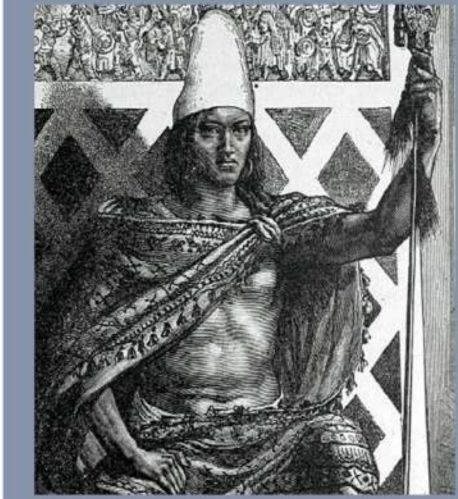
Aztec emperor's final resting place found

Words by **Owen Jarus**

The remains of an Aztec palace where emperor Moctezuma II was held captive by the Spanish and killed in 1520 has been discovered in Mexico City. Historical records say that the Spanish conquistador Hernán Cortés took Moctezuma hostage and held him in the palace in an attempt to force the emperor to control the Aztec population. The people quickly rebelled and laid siege to the palace. The Spanish tried to quell the rebellion by having Moctezuma address the rebels from a palace balcony, but the rebels refused to stop their siege and the emperor was killed in the crossfire.

The Spanish eventually destroyed the rebel forces along with the Aztec city of Tenochtitlan, where modern-day Mexico City is located. The surviving Aztec people were forced to build a new city over the ruins of Tenochtitlan. A house for Cortés, which was also discovered by archaeologists during the excavation, was built over the remains of the palace.

The discovery of the palace and Cortés' house revives the memory of those historical events, five centuries later. The discovery was made during excavation work conducted beneath the Nacional Monte de Piedad, a pawnshop founded in 1775. The excavation work was carried out prior to renovation work being done.



Source: Wiki Commons

Moctezuma II was the ninth Aztec emperor of Mexico, known for his confrontation with the Spanish conquistador Hernán Cortés

WISH LIST

The latest **university** gadgets

© Gocycle

Gocycle GX

Price: **£2,899 / $3,299** www.gocycle.com

With a 65-kilometre range on a seven-hour charge, the Gocycle GX is a great way to get around campus or between lecture buildings. This lithium-ion-battery-powered bike comes with three speed settings and can reach up to 25 kilometres per hour. The hydroformed aluminium frame also folds for easy storage on public transport or in a classroom. With a streamlined LED dashboard, you can monitor fuel levels, speed and gear levels to keep you in complete control of your ride.

Chipolo ONE

Price: **From £21 (approx. $27.50)**
www.chipolo.net

It's happened to us all at one time or another… you reach into your pocket or bag and quickly realise that your house or dorm keys aren't there. With the Chipolo ONE you can keep track of where you last left them. With the user-friendly app, Chiopolo can detect your keys from up to 60 metres away and can sound an alarm to alert you to their whereabouts. Similarly, if you've lost your phone, press the Chipolo and your phone will ring. The app's map feature will also let you know when you were last with your keys if you're out of range so you can retrace your steps.

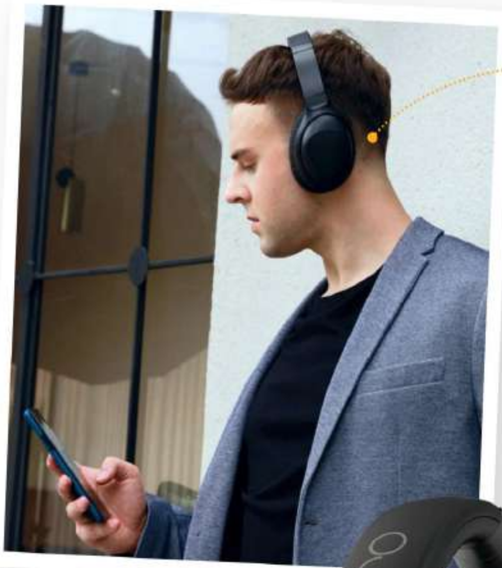
© Chipolo

© LaCie

LaCie Mobile Drive

Price: **From £94.99 / $94.99** www.lacie.com

We're always reminded to back up our assignments for an inevitable problem with our computers, usually the day before submission. But using an external hard drive is a sure-fire way to keep your work safe from any technological mishaps. The LaCie Mobile Drive is one such hard drive that can store a colossal amount of information, with storage capacities of up to five terabytes of data – that's around 500,000 high-resolution images or 165 hours of video.


© Puro Sound Labs

PuroPro™

Price: £152.60 / $199.99
www.purosound.com

Block out background noise, enjoy music and keep your hearing safe with these Bluetooth noise-cancelling headphones from Puro Sound Labs. With 28 hours of playtime with active noise cancellation (ANC), you can listen to your favourite tunes all day, perfect for a long day of studying. PuroPro™ is also equipped with five microphones – four for ANC and one for taking calls – and allows the listener to adjust the maximum volume to help protect your hearing.

WIN
a pair of these headphones!
Page 42

JBL Link Portable

Price: £129.99 / $179.95
uk.jbl.com

With built-in 360-degree sound, the JBL Link Portable is a great addition to any student household. This compact speaker is WiFi or Bluetooth connected, so you can stream music from Spotify, Apple Music or YouTube Music with ease. This portable speaker also doubles as a smart-home device with voice recognition, great for selecting songs or your favourite audiobook. With eight hours of portable playtime, this is gadget for long study nights.

© JBL

© Travelteq

The New Original Briefcase

Price: €425 (approx. £385 / $505)
www.travelteq.com

Sleek and stylish, this briefcase is smart in more ways than one. Not only a good-looking accessory, the New Original Briefcase by Travelteq has an integrated power pack with wireless charging capabilities. Great for keeping your smartphone juiced up while carrying your laptop and notes between classes, this briefcase also boasts an optional tracker so you don't have to worry about losing an assignment.

APPS & TOOLS

Otter Voice Meeting Notes

Developer: Otter.ai
Price: Free / Google Play / App store

Record and take notes with ease using this dictation app. Simply record your interviews, lectures or meetings and it will transcribe audio to text.

Run better meetings
Connect your calendar

Monthly Budget Planner & Daily Expense Tracker

Developer: DigitLeaf, llc
Price: Free / Google Play

Take control of your budget with this organisational app. Track your income and expenses with the built-in calculator and budget forecast feature.

Select categories
Disposable incomes
Salary/Wages
£0.00
Other Income
£0.00
Budgeted expenses categories
Home/Rent
£0.00
Daily Living
£0.00

Grammarly Keyboard

Developer: Grammarly, Inc.
Price: Free / Google Play / App Store

This grammar assistant helps you keep on top of your spelling, punctuation and sentence structure, a great tool for proofing your assignments.

Adjust keyboard look
q w e r
a s d
q w e r
a s d
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Number row

Anti-Social: phone addiction

Developer: Bugbean Pty Ltd
Price: Free / Google Play

Remove smartphone distractions with this temporary app locker so you can stay focused on tomorrow's deadline, and track your social media habits.

Usage Access
In order to monitor app usage we need you to grant AntiSocial usage access permission.

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HURR

ICANE POWER

HOW THE OCEAN CONCOCTS EARTH'S MOST VIOLENT STORMS - AND HOW WE'RE ABLE TO FLY RIGHT INTO THEM

Words by **Ailsa Harvey**

If the weather symbolised its emotions, Earth would have some dramatic mood swings. Over the course of a spring day in temperate parts of the world you can be exposed to illuminating sunshine, pouring rain and a torrent of hail as the weather changes its mind. But these changes are insignificant when compared to the violent outbursts that erupt from the middle of the planet's vast oceans.

In fact, the ocean could be considered the moodiest location on Earth, with its frenzied waves colliding at the surface, extreme currents pulling underneath and relentless gales rushing over the top. Covering the majority of the planet, this extensive body of water can move with mesmerising power.

Hurricanes are storms of tremendous size and wind speeds with the power to do devestating damage. Nothing living can outrun a hurricane, not even a cheetah – the world's fastest land animal. They're brought into existence by the connection between the ocean and the atmosphere. These swirling giants are formed from built-up pressure, where warm water is lifted from the ocean's surface and into the atmosphere to become an unstoppable force of spinning air. These massive storms have been known to reach sizes over 2,000 kilometres in diameter as they surge across water and land, displacing anything and everything in their path.

Hurricanes are an undeniable threat to humans because they are one of the rare products of Earth we have no control over. For those who

DID YOU KNOW?

19 million

trees were knocked down by Hurricane Floyd have witnessed their destruction firsthand, it can't be denied that they have the power to ruin lives.

Yet we still look at this power in awe. These enormous, whirling systems are concocted from natural forces alone. They occur spontaneously and maintain their astonishing peak force for many days at a time. As if armed for an attack on the land, they move with the wind while firing their weapons: wipeout waves, flooding rain and gusts of wind that put human-made shows of strength to shame.

Nature holds the ultimate power, whether that is used to destroy or to create. Looking past the ruinous aftermath that follows a hurricane, their path can also display some benefits to the environment. Moving in a rotating pattern around a calm centre, these storms help to maintain a global heat balance across the planet, without which the poles and tropics would have much more extreme temperatures.

There is already a stark difference between these areas, and with almost all hurricanes moving outwards from the equator, tropical storms channel heat energy effectively to colder waters.

A hurricane's job as an agent of dispersal doesn't end at sea. If their winds can make uprooting the thickest trees look effortless, imagine how easy it is for them to carry tiny, lightweight seeds that have evolved to harness the wind. With speeds and power unlike the gusts and breezes that many plants use to disperse seeds, hurricanes can spread plant species much further than the wind would. In some cases they have even brought distant areas destroyed by fires and other environmental disasters back to life.

Today we know more about hurricanes than we ever have, making the prediction of their emergence and their potential paths much easier. The importance of this lies not only in increased knowledge, but in warning communities and saving lives. So how can a hurricane be spotted in advance?

The National Hurricane Center (NHC) is responsible for overseeing tropical storm escalation, aiming to spot hurricanes 48 hours before they reach land. This might sound like something of a guessing game, but with the evolution of more advanced technology this process is made easier.

Satellites have become a main source for obtaining this information. Being further away from the storm allows the technology to analyse the activity more closely with a variety of sensors. Radars are used to track rain and wind speeds, while infrared sensors can monitor temperature differences within growing storms and help to locate their centres.

Once the whereabouts of volatile atmospheres are determined, aircraft can take a closer look, equipped with the tools to measure the intensity and direction of increasing winds. Down on Earth, ground stations, sea buoys and ships analyse areas where hurricanes are born.

Ocean buoys float at the surface of the water at common hurricane-forming sites. Moving with the waves and currents, they can measure wave height, swell direction and the surrounding wind, air and water temperatures and pressures. When changes in these conditions begin to turn towards those ideal for a hurricane birth, meteorological centres can be alerted.

What's in a name?

Each hurricane has unique qualities, forges its own path and carries varying levels of destruction, so a method to differentiate between them is needed. The US began using short, memorable names in 1953 to avoid confusion between storms and to communicate their danger quickly. The World Meteorological Organization controls the naming using the following procedure.

There are six lists of names. They alternate between male and female and contain all the letters of the English alphabet minus Q, U, X, Y and Z. This removes any difficulty in name pronunciation. Each list from A to W is followed each year, and if there happen to be more hurricanes than letters in a season, the names move on to the Greek alphabet.

WORLD METEOROLOGICAL ORGANIZATION
ORGANISATION METEOROLOGIQUE MONDIALE

© Getty

Before the World Meteorological Organization was founded, hurricanes were given numbers

Being given this wide array of information, forecasters need to put together a likely picture by feeding all this data into a superfast computer. But although scientists know what conditions are needed to form a hurricane, they don't know why one doesn't occur every time the conditions are right. For this reason the activity within the ocean and atmosphere has to be closely monitored. As soon as tropical storms begin to accelerate towards Category 1 speeds, they use global wind patterns to plot the potentially impacted land mass. Drawing out multiple path possibilities, populations which could be affected can be warned in advance.

These awesome forces of nature can usually be observed between June and November, with hurricane season peaking between August and October. It is impossible to put up a fight against these power-accumulating wind towers, so the best thing to do is give them right of way and stay clear of their predicted paths. Evidence shows that recent hurricanes are intensifying more quickly in the last few years, so watch out the next time nature kicks up a storm.

A hurricane is more than capable of tearing a house to pieces

© Getty

DID YOU KNOW?

8,000 deaths

The deadliest hurricane took place in 1900

DID YOU KNOW? *Hurricanes release heat equivalent to a ten-megatonne nuclear bomb exploding every 20 minutes*

ESSENTIAL INGREDIENTS

These components are vital for the formation of these intense storms

Weather disturbance

Hurricanes develop from previous weather disturbances. A tropical storm begins as an area of low atmospheric pressure.

Warm water

The ocean needs to be at least 26.5 degrees Celsius, covering depths of 50 metres.

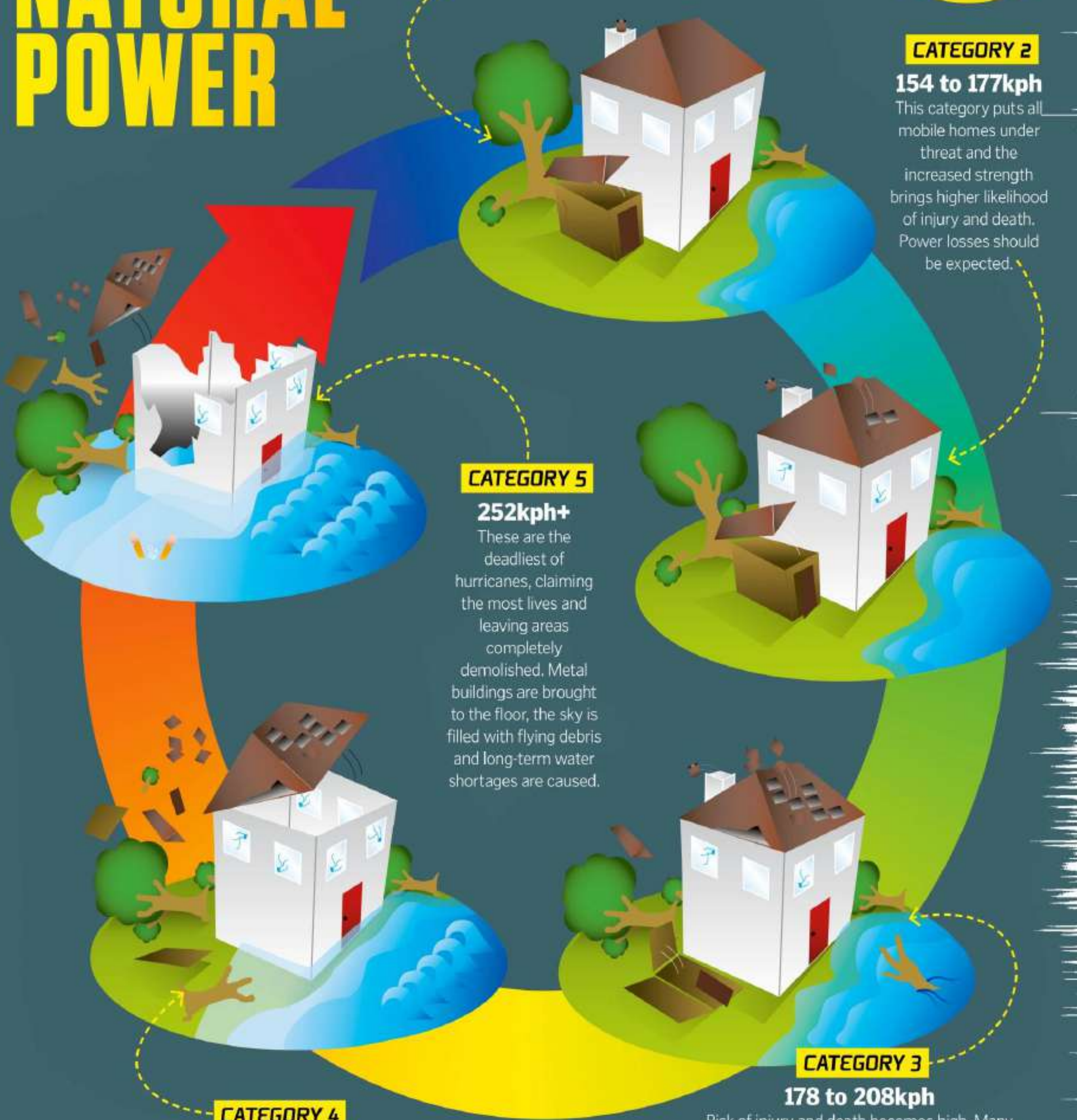
Thunderstorm

Thunderstorms are built into something larger, stronger and more explosive.

Wind

Air needs to travel vertically from the ocean, creating a lifting mechanism.

RATING NATURAL POWER



CATEGORY 1

119 to 153kph

Although it's the lowest category, danger can be displayed in falling debris and the destruction of older mobile homes. Protected glass windows are likely to survive intact, but snapped power lines can leave impacted areas in darkness.

CATEGORY 2

154 to 177kph

This category puts all mobile homes under threat and the increased strength brings higher likelihood of injury and death. Power losses should be expected.

CATEGORY 3

178 to 208kph

Risk of injury and death becomes high. Many houses and flats are subjected to significant damage and the storm tears trees from the ground. Affected areas can have to live without water and electricity for weeks.

CATEGORY 4

209 to 251kph

The risk to life is now very high. Hurricanes in this category will break most windows in high-rise buildings and blow the roofs off houses. Power damage and water shortages mean areas can become impossible to live in, sometimes for months.

CATEGORY 5

252kph+

These are the deadliest of hurricanes, claiming the most lives and leaving areas completely demolished. Metal buildings are brought to the floor, the sky is filled with flying debris and long-term water shortages are caused.

DID YOU KNOW?

2005

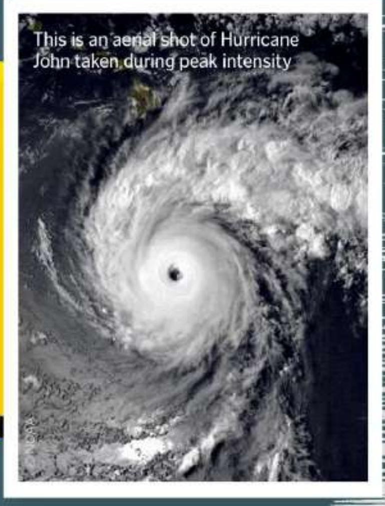
This was the most active Atlantic hurricane season on record, with 27 named storms

Where are they found?

Ocean water closest to the equator is the warmest because it's more exposed to direct solar radiation. Because this warmth is required to begin the movement of air particles, it is close to this central line where tropical storms usually brew.

Hurricanes, cyclones and typhoons all form along this line, but what makes them different from each other? The answer is nothing. These are simply three titles for the same weather pattern, given a variation in name depending on the region where they form.

Once in action, the route taken by these violent bursts and the time the storms last can be diverse. Their paths are steered by global winds and their life span depends on strength and access to fuelling resources along their path. While an average hurricane will last for several days, Hurricane John sustained its power for 31 days in 1994.



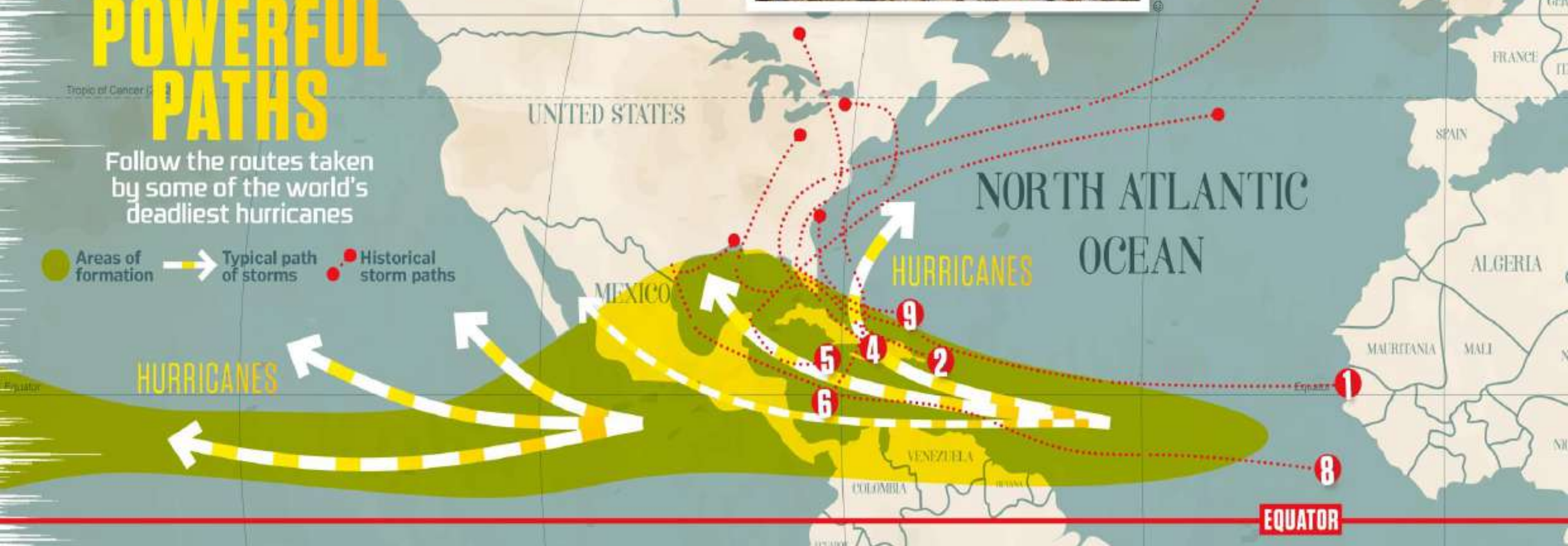
This is an aerial shot of Hurricane John taken during peak intensity

POWERFUL PATHS

Follow the routes taken by some of the world's deadliest hurricanes

9 Dorian
The aftermath of Dorian is shown here after its route through Marsh Harbour in the Bahamas, 10 September 2019.

© Getty



7 Haiyan
This is what the houses in the city of Iloilo looked like after Typhoon Haiyan.

© Getty

8 Harvey
Hurricane Harvey had a massive impact on the roads in Texas.

4 Katrina
A pile of debris shows the strength of Hurricane Katrina in Mississippi.

© Daniel Lo

HURRICANES THROUGH HISTORY

1 Okeechobee

Date: **6-21 September 1928**
Category: ●●●●●
Deaths: **4,000+**

Okeechobee made landfall near West Palm Beach, Florida, late on 16 September, tearing up the land and homes and taking lives. Days before the hurricane had already claimed the lives of about 1,500 people in the Caribbean. The worst impacted area on the mainland was Lake Okeechobee, which gives the hurricane its name. This region was used primarily for farming, and although a small dyke had been built to protect the land, it was no match for Okeechobee's 225-kilometre-per-hour winds. Many workers were drowned in the flooded fields, caused by a storm surge.

2 Labor Day Hurricane

Date: **29 August - 10 September 1935**
Category: ●●●●●
Deaths: **485**

One reason why this hurricane cost the lives of hundreds is due to the underestimation of its scale. Hitting Florida Keys on 2 September, the hurricane obliterated the coast, where World War I veterans had been sent to build roads and bridges. 250 of them died doing this work because the organisers were unaware of the intensity of the incoming storm. Slamming into a 64-kilometre section of the coast, almost all human-made structures were ripped apart and the workers stood no chance in the fight for their lives. At the time it was the most intense hurricane to hit the US.

3 Bhola cyclone

Date: **3-13 November 1970**
Category: **Cyclone**
Deaths: **500,000+**

This tropical storm is a cyclone, which forms over the South Pacific and Indian Oceans. Bhola was one which caused severe havoc in both India and Bangladesh, then named East Pakistan. Those living on the coast had no idea of what was to come as meteorologists had no way of communicating with most living in the area. As they slept the cyclone crossed the land, carrying a wave of water six metres high and winds of over 225 kilometres per hour. Bhola is one of the deadliest natural disasters in recent history.

4 Katrina

Date: **23-31 August 2005**
Category: ●●●●●
Deaths: **1,800+**

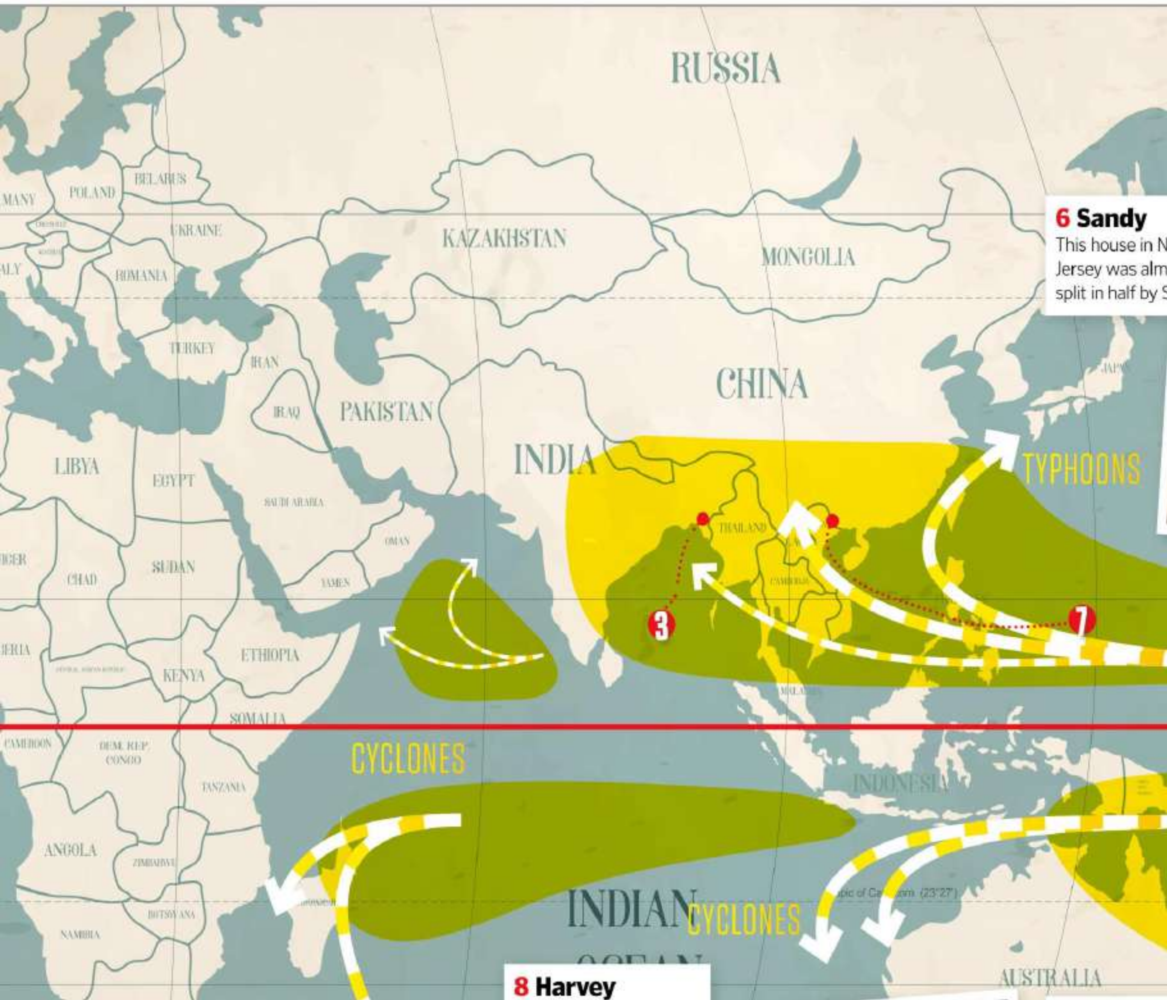
When Katrina reached land in Louisiana, it was at Category 3, but it grew to a width which could reach across the entire Gulf of Mexico. Impacting great stretches of land, signs of Katrina's presence remained for over a decade. Criticising the preparation in place for such a storm, the search and rescue response and following action, Barack Obama said: "What started out as a natural disaster became a man-made disaster… a failure of government to look out for its own citizens."

5 Wilma

Date: **15-27 October 2005**
Category: ●●●●●
Deaths: **87**

Within 24 hours of becoming a hurricane near Jamaica, Wilma developed into a rapid Category 5, crossing two peninsulas. These were Mexico's Yucatán Peninsula, where some towns were flooded by rainfall of over one-and-a-half metres, and Florida, which it crossed in just four-and-a-half hours. In this limited time 6 million residents in Florida lost electricity for two weeks, while damage to sugar cane and other crops due to flooding made the hurricane one of the most expensive.

DID YOU KNOW? *Hurricanes that form north of the equator spin anti-clockwise, while southern ones spin clockwise*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CAMBODIA
MALAYSIA
TYPHOONS
3
7
CAMEROON
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TANZANIA
CYCLONES
INDONESIA
ANGOLA
ZIMBABWE
BOTSWANA
NAMIBIA
INDIAN OCEAN
CYCLONES
Tropic of Capricorn (23°27')
AUSTRALIA
SOUTH AFRICA

6 Sandy
This house in New Jersey was almost split in half by Sandy.

8 Harvey
Flooding in Texas can be seen in this aerial shot.

© Getty

6 Sandy
Hurricane Sandy put this restaurant underwater on 30 October 2012.

POURHOUSE
BAR & GRILL
© Getty

3 Bhola cyclone
Villagers search for salvageable rice and grains following the cyclone in East Pakistan.

© Getty

6 Sandy

Date: **22 October - 2 November 2012**
Category: ●●●○○
Deaths: **285**

As it raged into mainland America, the hurricane became trapped by another storm. Having another nearby high-pressure storm meant that Sandy was unable to leave New Jersey and Delaware. As the two storms merged and became trapped along the coast, the increased scale of the affected area and persistence of the brutal winds rendered many people homeless - if they managed to survive.

DID YOU KNOW?
13,280km
Hurricane John travelled a distance greater than the diameter of Earth

7 Typhoon Haiyan

Date: **3 - 11 November 2013**
Category: **Super typhoon**
Deaths: **7,000+**

Targeting the islands of the Philippines, Haiyan is one of the strongest typhoons ever recorded. Subjecting the islands to seven-metre-high waves and relentless rainfall, the storm had a severe impact on the country's economy and killed people in devastating numbers. Of those who were lucky enough to walk away from the event, 1.9 million were left homeless. Not only does this storm highlight the impact on people's lives, it also shows how they can tear apart the environment. The uprooting of thousands of trees meant there was a significant loss in habitat for wildlife, creating a decline in biodiversity.

8 Harvey

Date: **17 August - 2 September 2017**
Category: ●●●●○
Deaths: **68**

Having made a pit stop in the Gulf of Mexico, Hurricane Harvey was ready to attack Texas with its power. It had just refuelled in the deep, warm water and would soon show off its newfound strength. While it was in the second-strongest category as it made landfall, the hurricane soon weakened, staying in one place for a prolonged period. As a result the total death toll is much lower than some of the other Category 4 hurricanes that came before it. What it didn't take in lives, however, it made up for in land. The mass flooding which came with the hovering hurricane destroyed the homes of 135,000 people in the area.

9 Dorian

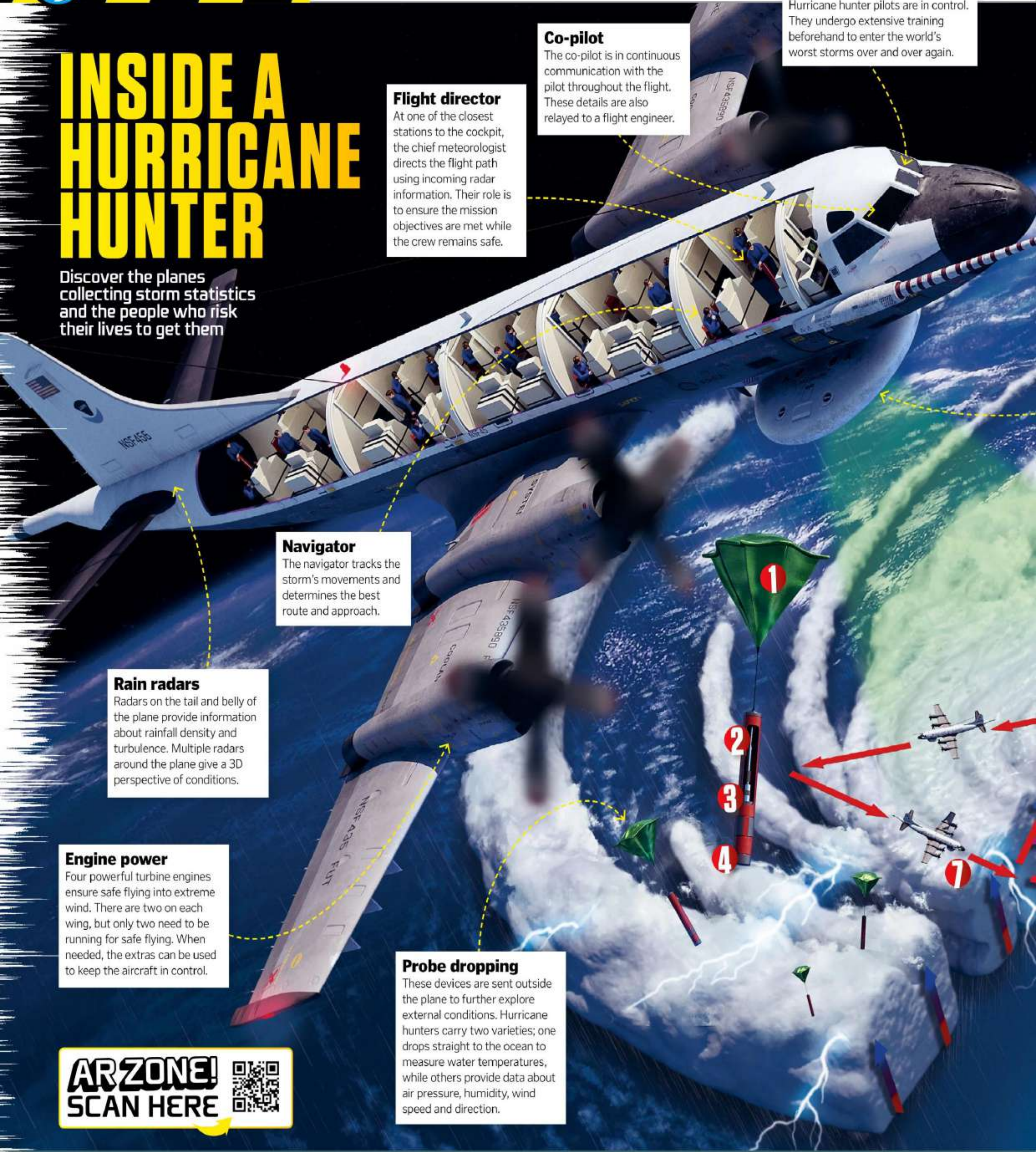
Date: **24 August - 10 September 2019**
Category: ●●●●●
Deaths: **84**

Although classed as the slowest moving major hurricane on record, Dorian was one of the most catastrophic. Spending much of its progression above water, it was able to sustain a relatively long life span. Unfortunately for those in the Bahamas at the time, the route it took happened to trace the islands. Not only was this a lingering storm, but it is the strongest hurricane to have hit the Bahamas and one of the strongest across the entire Atlantic.

DID YOU KNOW?
90%
of hurricane deaths are due to flooding

INSIDE A HURRICANE HUNTER

Discover the planes collecting storm statistics and the people who risk their lives to get them



Pilot
Hurricane hunter pilots are in control. They undergo extensive training beforehand to enter the world's worst storms over and over again.

Co-pilot
The co-pilot is in continuous communication with the pilot throughout the flight. These details are also relayed to a flight engineer.

Flight director
At one of the closest stations to the cockpit, the chief meteorologist directs the flight path using incoming radar information. Their role is to ensure the mission objectives are met while the crew remains safe.

Navigator
The navigator tracks the storm's movements and determines the best route and approach.

Rain radars
Radars on the tail and belly of the plane provide information about rainfall density and turbulence. Multiple radars around the plane give a 3D perspective of conditions.

Engine power
Four powerful turbine engines ensure safe flying into extreme wind. There are two on each wing, but only two need to be running for safe flying. When needed, the extras can be used to keep the aircraft in control.

Probe dropping
These devices are sent outside the plane to further explore external conditions. Hurricane hunters carry two varieties; one drops straight to the ocean to measure water temperatures, while others provide data about air pressure, humidity, wind speed and direction.

AR ZONE! SCAN HERE

1 Probe parachute
Parachutes allow for a slower fall, giving time for the probe to collect data. It takes seven minutes for the probe to fall from six kilometres.

2 GPS antenna
Data from GPS satellites is collected to calculate wind speed and direction.

3 Microprocessor
This tiny device takes the data from the sensors and digitises them.

4 Radio transmitter
Every 0.5 seconds, this sends temperature, humidity, pressure and wind data back to the plane's computers.

5 Into the eye
The plane makes its first flight through the centre of the hurricane. Passing through the walls of the eye is the windiest and bumpiest section. It is here that the probes are dropped.

6 First crossing
After crossing through the entire hurricane, researchers on board have a good understanding of the conditions throughout.

DID YOU KNOW? *The fastest wind ever measured on Earth's surface came from Cyclone Olivia, at 407kph*

HOW HURRICANES FORM

A combination of forces create these mighty spectacles

1 Moist air

Hurricanes only form over warm waters. As the moist air is heated by the ocean it rises away from the water and pressure builds just above the surface. This warm air is the storm's fuel.

2 Begin to spin

To replace the rising air, surrounding particles move into the gap left behind. These then warm and rise, creating a cycle of particle movement. This ongoing displacement of air moves in a spinning motion.

3 Whirling winds

As wind increases, moving air particles in the centre push into the spiralling wind. With nowhere else to travel, this forces the air to move upwards at the centre.

4 Creating clouds

Having risen, the air is cooled and begins to form clouds where thunderstorms can take place.

5 Growing system

As air continues to rise and cool, the cloud and wind system continues to expand and spin.

6 Descending air

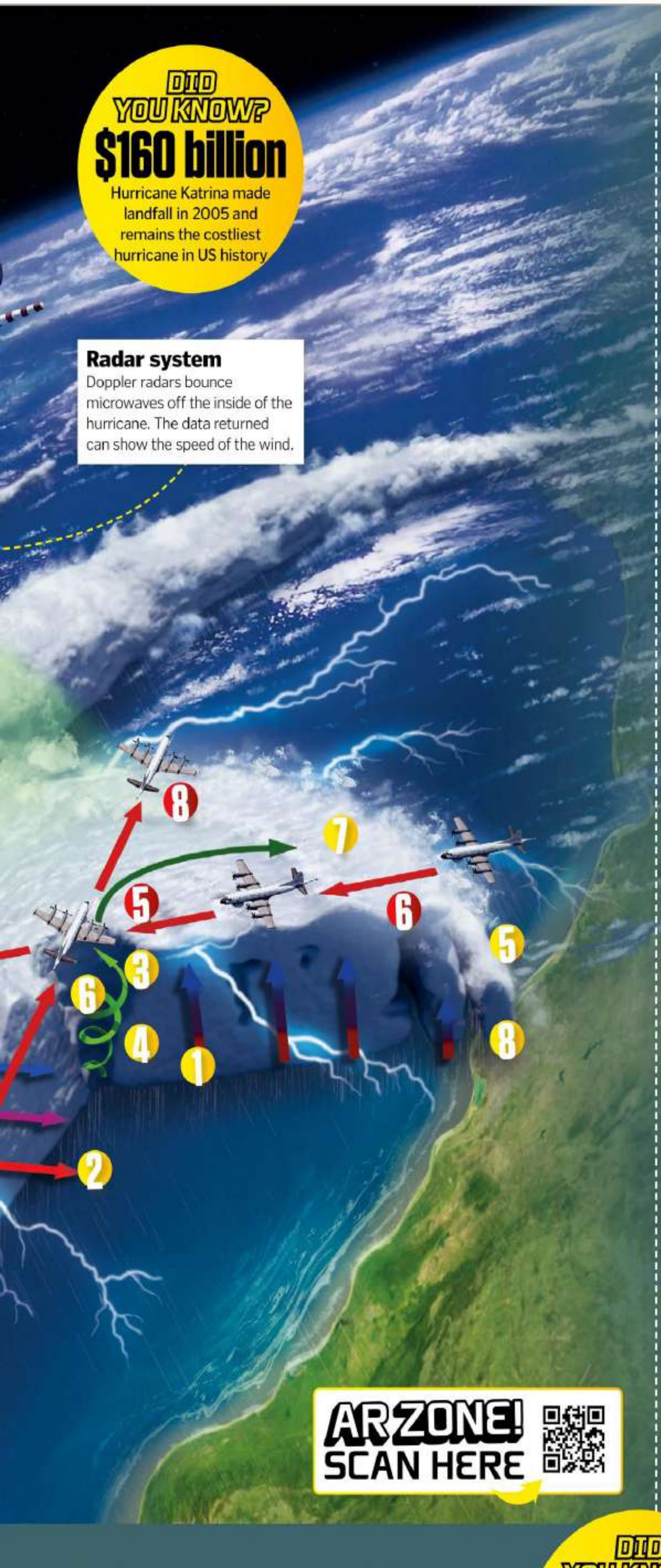
The storm gains speed and an eye forms at its centre. This clear section has a low pressure and forces high-pressure air from above it down into the massive central space.

7 Classification

Speeds progressively increase. When they reach 119 kilometres per hour, a hurricane is born.

8 Land limit

When travelling across land, the moisture and heat fuelling the hurricane stop the upward flow. The hurricane will continue to move over land until it loses energy.



DID YOU KNOW?

$160 billion

Hurricane Katrina made landfall in 2005 and remains the costliest hurricane in US history

Radar system

Doppler radars bounce microwaves off the inside of the hurricane. The data returned can show the speed of the wind.

AR ZONE! SCAN HERE

7 Crisscross

The plane takes its position to cross through the storm for a second time. Hurricanes can evolve so quickly that it may seem like an entirely different storm upon second entry.

8 End of route

The more the plane journeys into the storm, the more data will be collected. This route can sometimes be endured several times.

DID YOU KNOW?

252kph

The most powerful hurricanes have winds with speeds the same as a free-falling skydiver

© Illustration by Nicholas Forder

Storm chasers

While most people warned of a hurricane's approach plan their escape, some people don't run. It is their job to put themselves at the centre of these storms. One of the essential methods used to collect hurricane data is to fly straight into a storm. Unsurprisingly, being at the centre of a Category 5 hurricane isn't the safest place to find yourself. However, the planes used are specially designed for smooth flying under the stress of one of Earth's most unforgiving forces.

You might expect the strongest hurricanes to present the most challenges, but crews on these planes have said otherwise. It's actually the unpredictability of the ever-changing conditions that create sudden danger.

© Science Photo Library

This photo was taken from inside the eye of Hurricane Floyd

Surfing the storms

While most adhere to precautionary measures and prioritise their safety, some people travel towards the shore, ready to take on what the storm has to offer. In this case the offering is big waves, and for many surfers this is the ultimate challenge.

Hurricane-generated swells are rare, more dangerous and everything these thrill-seekers crave. The towering waves are generated at the centre of storms. As water rises from the eye of the storm, it mixes with the high winds and currents, creating a surge of water. The closer the hurricane gets to land, the wilder the waves.

© Getty

A surfer rides waves caused by Hurricane Rosa in 2018

RISE OF THE MARSUPIALS

Why are Australia's indigenous mammals so different to animals in other continents?

Words by **Scott Dutfield**

Australia is no stranger to the weirder side of evolution, with the likes of patchwork platypuses and egg-laying, hedgehog-like echidnas roaming the land. However, it has also become the home of one particular group of mammals: marsupials.

Found hidden beneath the ground, hopping through grasslands or hanging among treetops, Australia hosts a majority of Earth's marsupials. Around 250 species of these pouch-bearing parents live throughout the southern continent – that's more than anywhere else in the world. There are 120 species in South America and only one species, the Virginia opossum, is found in North America. This abundance has led some to believe that marsupials first evolved in Australia. However, that is not the case. It took millions upon millions of years for marsupials to make their way over to what would become the world's smallest continent.

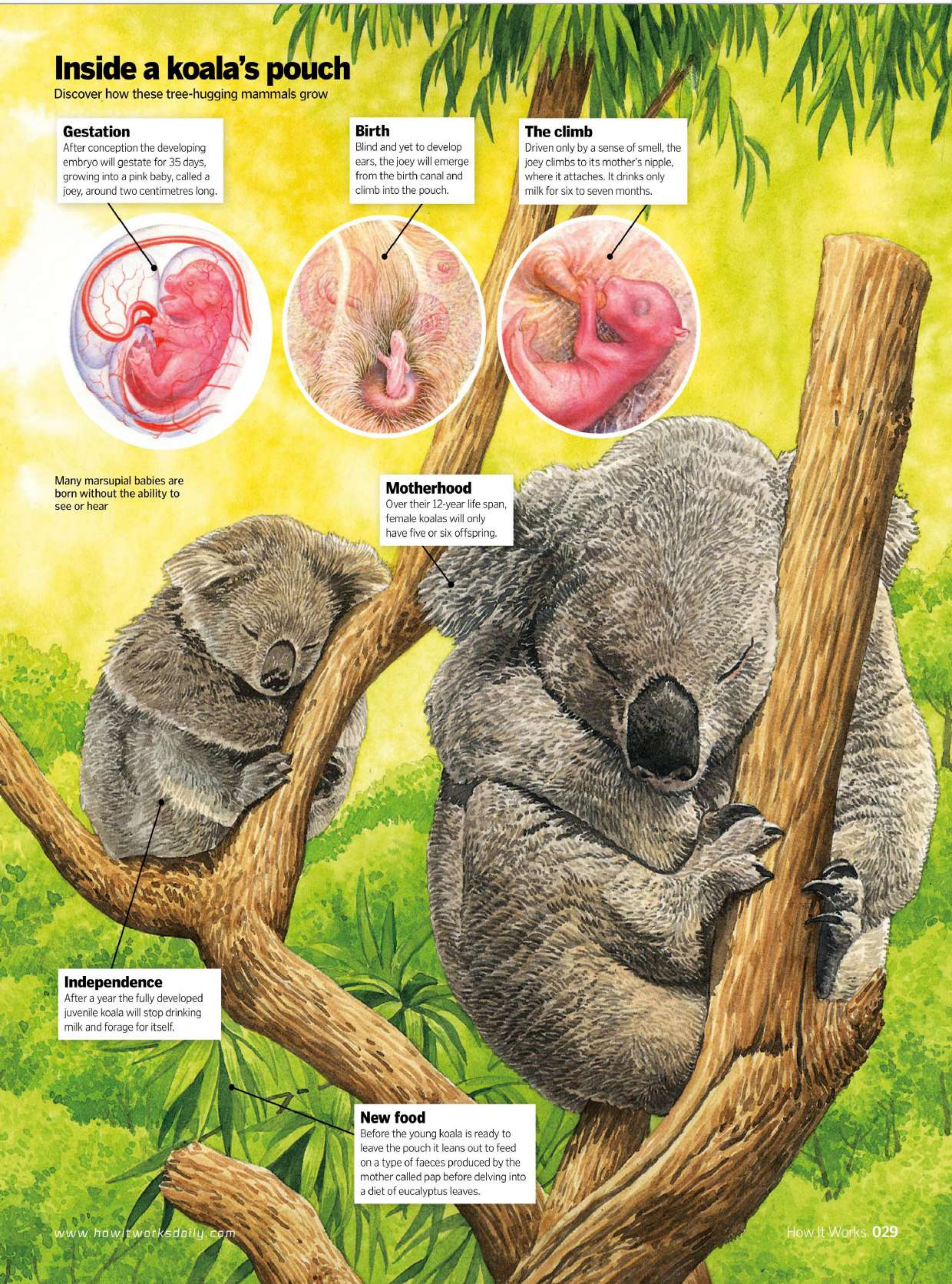
> "This created an opportunity for early marsupials to use land bridges between what later became separate continents"

What does it mean to be a marsupial? How have the different species adapted as parents and what was their evolutionary journey across half the world to build the current kingdom of the marsupials like? Home to the springing kangaroo, tree-clinging koala and burrowing wombat, Australia is well known for the diversity in its species and for being home to mammals that are rarely found around the rest of the world. The kangaroo, koala and wombat are native Australian species – and are all marsupials, of course. This means that the way they give birth and support their young is different from other placental mammals such as humans, elephants and bears.

All images © Getty unless otherwise stated

Inside a koala's pouch

Discover how these tree-hugging mammals grow



Gestation
After conception the developing embryo will gestate for 35 days, growing into a pink baby, called a joey, around two centimetres long.

Birth
Blind and yet to develop ears, the joey will emerge from the birth canal and climb into the pouch.

The climb
Driven only by a sense of smell, the joey climbs to its mother's nipple, where it attaches. It drinks only milk for six to seven months.

Many marsupial babies are born without the ability to see or hear

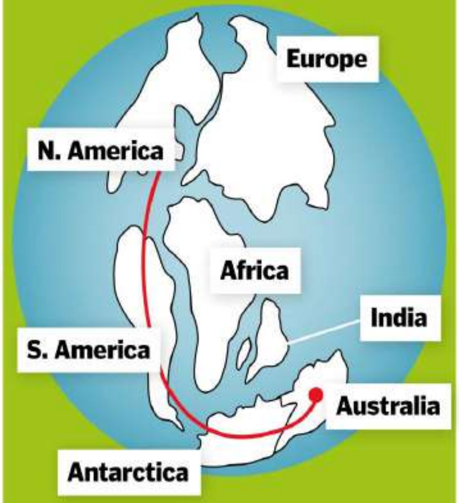
Motherhood
Over their 12-year life span, female koalas will only have five or six offspring.

Independence
After a year the fully developed juvenile koala will stop drinking milk and forage for itself.

New food
Before the young koala is ready to leave the pouch it leans out to feed on a type of faeces produced by the mother called pap before delving into a diet of eucalyptus leaves.

Travelling to Australia

How marsupials migrated to the other side of the world



The journey begins

Around 66 million years ago marsupials made their way down from North America to South America. Although at the time the two land masses were not connected, it's thought land bridges or islands may have allowed them to migrate.

Heading south

Once in South America the number of different marsupial species increased, and although today most of those species are extinct, South America still has the second-highest diversity of marsupials.

Crossing Antarctica

While South America was still attached to Antarctica and Australia – before splitting 40 to 35 million years ago – some marsupial species hot-footed across the land masses to populate Australia. During the time of their evolutionary migration, Antarctica, like many other parts of the world, would have been filled with tropical rainforests.

New home

The first fossil evidence of marsupials in Australia dates back 55 million years. Since the continents broke apart Australia could not be reached by the placental mammals dominating the rest of the world, leaving marsupials to thrive.

Placental mammals carry their offspring internally, where they are nourished by a specialised organ called the placenta until the developing fetus is fully grown and ready to be born. Marsupial babies, however, are born at a stage when they are still developing.

Rather than facing the outside world immediately as human babies do, a marsupial joey will climb its way into a protective pouch on the mother where it will continue to develop until it's fully formed. This also means gestation time can be surprisingly shorter in some species compared to their placental cousins. For example, the mouse-like stripe-faced dunnart has a gestation period of only 11 days before the fetus is birthed into its parent's poach.

But why is Australia inhabited by so many of these marsupial mammals compared to the rest of the world? It's easy to assume that marsupials must have evolved on the Australian continent because it's an island without a geographical bridge over which they could venture outside its borders and form new populations. But that's not strictly true. The first marsupials appeared in what is now North America 160 million years ago, when Earth's supercontinent Pangea connected the world's land masses as one. This created an opportunity for early marsupials to use land bridges between what later became separate continents, allowing them to move around to form new populations. Over millions of years the ancestors of modern-day marsupials found themselves on the Australian continent without strong competition from the placental mammals evolving elsewhere around the world.

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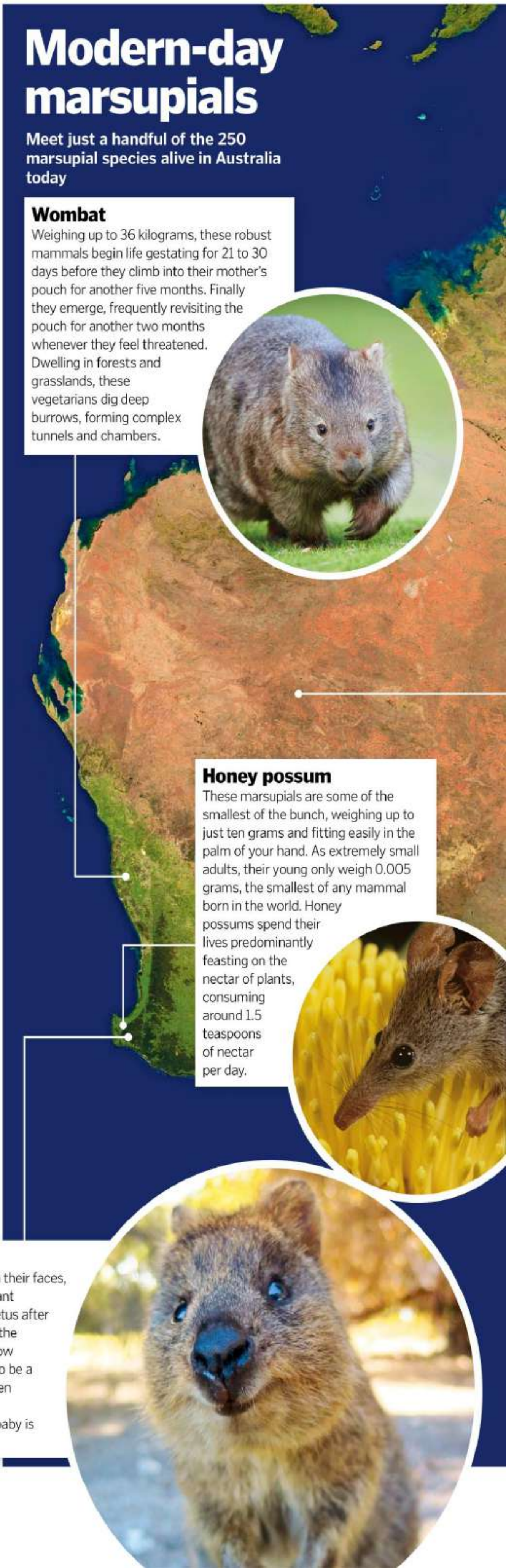
Modern-day marsupials

Meet just a handful of the 250 marsupial species alive in Australia today



Wombat

Weighing up to 36 kilograms, these robust mammals begin life gestating for 21 to 30 days before they climb into their mother's pouch for another five months. Finally they emerge, frequently revisiting the pouch for another two months whenever they feel threatened. Dwelling in forests and grasslands, these vegetarians dig deep burrows, forming complex tunnels and chambers.

Honey possum

These marsupials are some of the smallest of the bunch, weighing up to just ten grams and fitting easily in the palm of your hand. As extremely small adults, their young only weigh 0.005 grams, the smallest of any mammal born in the world. Honey possums spend their lives predominantly feasting on the nectar of plants, consuming around 1.5 teaspoons of nectar per day.

Quokka

Often seen with what appears to be a smile on their faces, Quokkas are one of Australia's eternally pregnant marsupials. With the ability to give birth to a fetus after 27 days, while the new offspring is suckling in the mother's pouch, another fetus can begin to grow internally. This baby conveyor belt is believed to be a good defence mechanism for the Quokka. When threatened it can evict the suckling young as a distraction to escape, reassured that another baby is growing inside.

Numbat

Around 50 centimetres in length including their bushy tails, these small marsupials gestate for 14 days then carry their pouch-bound fetus for nine months before it is able to forage for insects itself. Numbats have a long, slender tongue that scoops up termites from leaf litter and deadwood – up to 20,000 of them a day! There's enough water in these termites that numbats don't have to drink any.

Greater bilby

They might look like rabbits, but they are far from it. This endangered marsupial lives in semi-arid shrubland and has large ears to compensate for its poor eyesight. The greater bilby is capable of giving birth up to four times a year, producing eight offspring at a time. By only five months old, these marsupials are fully grown and ready to reproduce.

Eastern quoll

The size of a small domesticated cat, the eastern quoll can be found in southeastern areas of Australia in dry grassland feasting on insects and small mammals. These marsupial mothers can grow 30 fetuses at a time. However, they are only able to feed between six and eight babies in their pouches, leading to many fatalities. After only ten weeks in the pouch the babies are placed in grass-lined dens, allowing the mother to hunt and retrieve food.

> "Often seen with what appears to be a smile on their faces, Quokkas are one of Australia's eternally pregnant marsupials"

Source: Wiki / PD/ CC / Reto Stöckli / NASA Goddard Space Flight Center

What is a petrified forest?

How a forest of green trees turns to stone and rubble

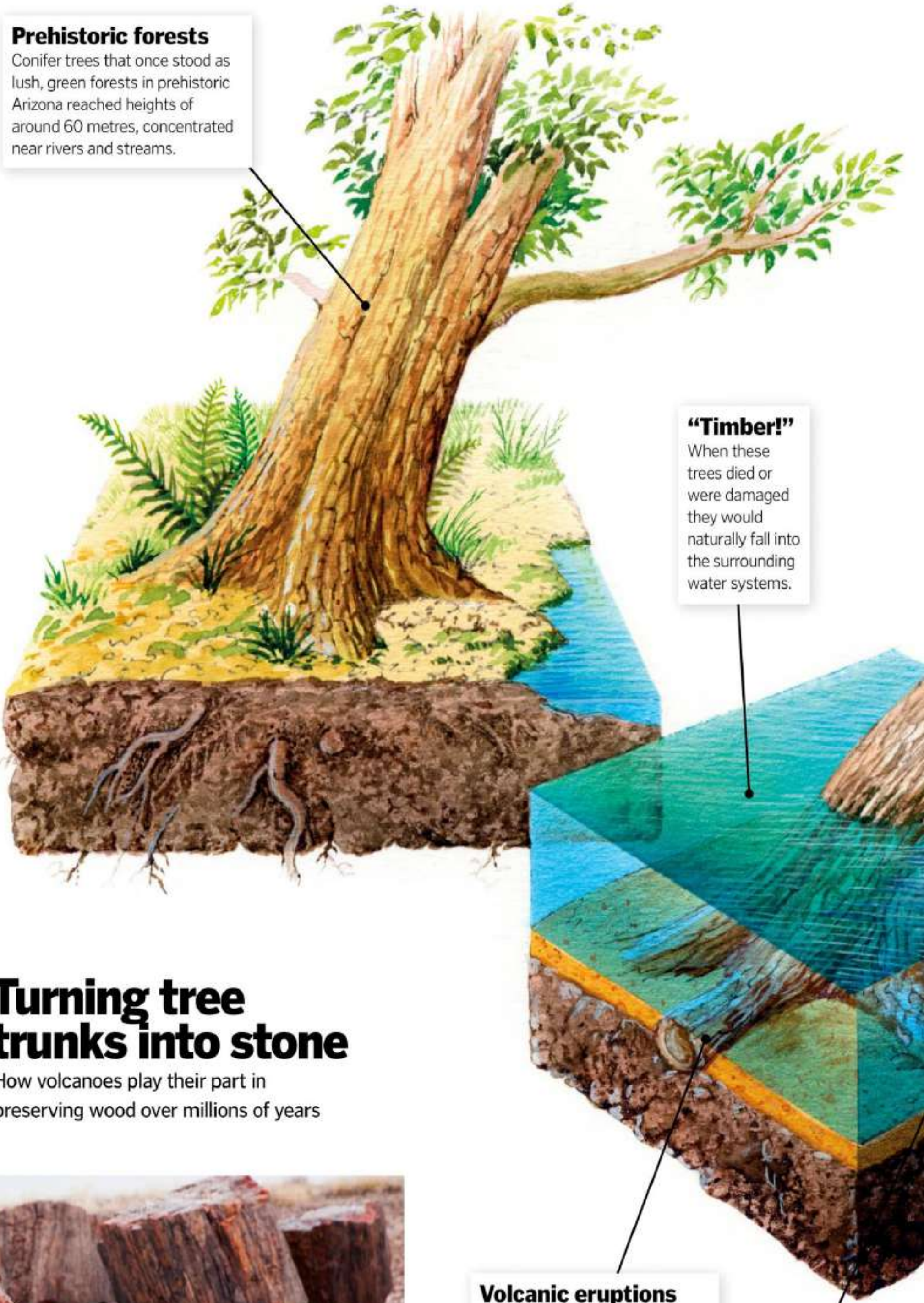
Baking in the Arizona sunshine is a forest frozen in stone. Spanning 896 square kilometres, the Petrified Forest National Park is a vast, arid site filled with undulating hills and rocky outcrops all staying dry in the hot weather. But it wasn't always this way.

Travelling back more than 225 million years, the almost-barren land today once flourished with towering conifers and trickling rivers. However, during Earth's evolutionary journey to the modern day, the land was stripped of its once-luscious green foliage. Instead it has been left with the petrified shadow of a forest that once was. As if having stared into the eyes of Medusa, solid stone tree trunks litter the ground. They are the same trees that once stood tall in a living forest, but over time have undergone a type of preservation known as petrification.

Unlike the creation of tree fossils, where the carbon-rich wood is compacted by mounting mud and rocks, petrification is a process whereby minerals are displaced from one source and incorporated into the remains of a once-living organism. This form of natural preservation occurs not only in ancient trees, but across the spectrum of life on Earth. For example, the bodies of migrating birds that have fallen into Lake Natron in northern Tanzania have undergone a calcification whereby their remains are chemically preserved with calcium from the alkaline lake water – albeit in a much shorter time frame than the stone wood in the Petrified Forest. It's taken millions of years for the types of preserved wood found in Arizona to form, and it's not the only place in the world to showcase forests of the past. Throughout America and as far as Greece, these stone forests offer a glimpse into a world long forgotten.

Turning tree trunks into stone

How volcanoes play their part in preserving wood over millions of years



Prehistoric forests
Conifer trees that once stood as lush, green forests in prehistoric Arizona reached heights of around 60 metres, concentrated near rivers and streams.

"Timber!"
When these trees died or were damaged they would naturally fall into the surrounding water systems.

Volcanic eruptions
Over time volcanic explosions caused tonnes of ash to enter into the atmosphere, settling into water that trees had fallen into.

Absorption
The minerals that make up volcanic ash, such as silica, are then soaked up by the submerged wood.

The Petrified Forest was designated a national park in 1962

© Getty

© Getty

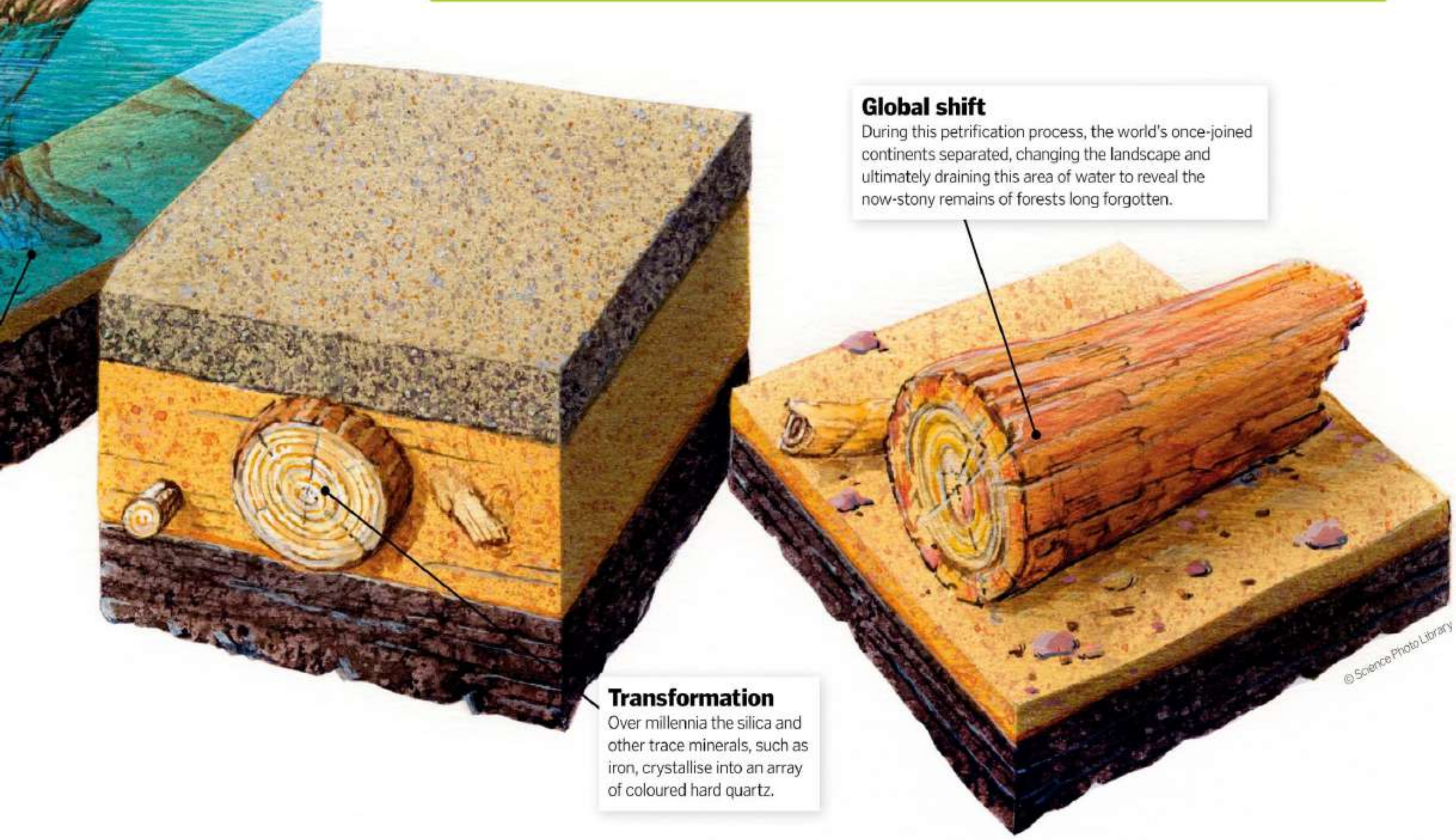
The National Park is a beautifully haunting sight

Colour of petrification

These elements give petrified wood its beautiful, glassy and colourful appearance

- Carbon, manganese
- Copper, chromium, iron
- Iron
- Natural quartz
- Copper, iron

© Getty



Global shift

During this petrification process, the world's once-joined continents separated, changing the landscape and ultimately draining this area of water to reveal the now-stony remains of forests long forgotten.

Transformation

Over millennia the silica and other trace minerals, such as iron, crystallise into an array of coloured hard quartz.

© Science Photo Library

Octopuses

Discover the incredible abilities of these eight-limbed wonders of the natural world

Octopuses are sort of like the superheroes of the animal kingdom, with so many amazing abilities and adaptations that they begin to look greedy. They can solve mazes, open screw-top jars and use tools. They can walk, they can swim and they can even propel themselves at high speed. They can change colour, imitate other animals, squirt ink, inject poison and jettison their own arms. When you can do all of that, who cares if you can predict the future or not?

Although they are molluscs, octopuses don't have a shell or bones. The only hard part of their body is a small beak, made of keratin. This allows them to squeeze through extremely small gaps – an octopus a metre across can pass through a tube the size of a 50 pence coin. Octopuses mainly eat crabs and small fish that they pull out of crevices in rocks and coral reefs, but they can also tackle small sharks by enveloping the sharks' gill openings and suffocating them.

Octopus blood uses a greenish-blue copper pigment called haemocyanin instead of the iron-based haemoglobin in our own blood. Haemocyanin can't carry as much oxygen as haemoglobin, but is actually more efficient at low oxygen concentrations and in cold water. Despite this octopuses have poor circulation and quickly run out of energy. This may be one of the reasons for their intelligence – they don't have the stamina for a prolonged chase and must rely on their cunning.

Male octopuses die almost immediately after mating. The females are even bigger martyrs. They guard their eggs for months, or sometimes years, and rather than leaving the nest to hunt they will eat some of their own arms. After that the female dies, and the eggs hatch into babies around the size of a walnut.

The statistics

© H Zell

Octopus

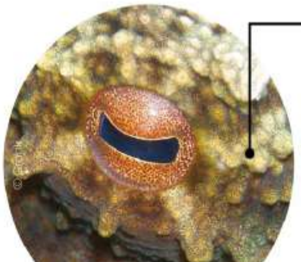
Class: Cephalopod

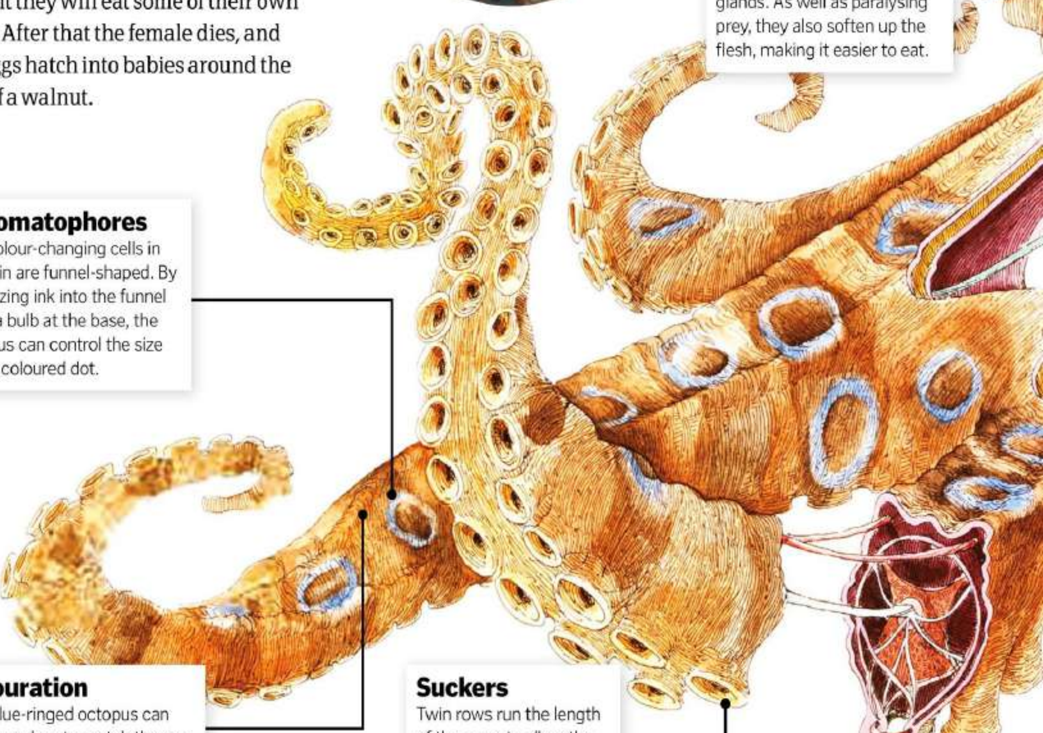
Diet: Carnivore

Average life span in the wild: Six months to five years

Weight: 0.1 to 200 kilograms

Size: Up to nine metres





Eye

This looks much like our own, with a lens and an iris, but it evolved in a different way. Octopuses don't have a blind spot where the optic nerve passes through because the retina is positioned differently.

Poison glands

These evolved from salivary glands. As well as paralysing prey, they also soften up the flesh, making it easier to eat.

Chromatophores

The colour-changing cells in the skin are funnel-shaped. By squeezing ink into the funnel from a bulb at the base, the octopus can control the size of the coloured dot.

Colouration

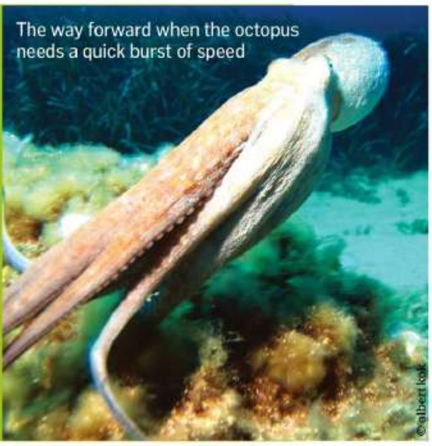
This blue-ringed octopus can change colour to match the sea bed or suddenly flash its bright, blue rings to startle predators.

Suckers

Twin rows run the length of the arms to allow the octopus to grip and to taste anything it touches.

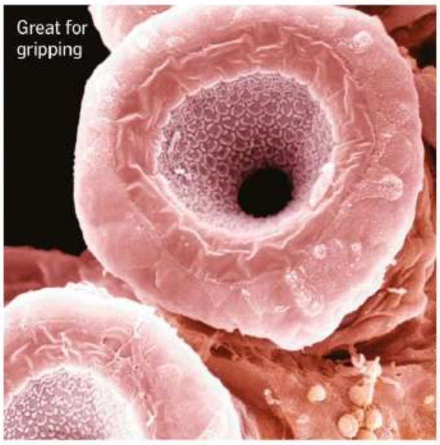
Jet-propelled

Octopuses normally swim by pulsing their arms, like the bell of a jellyfish. This is quite energy efficient, but it lacks acceleration. When an octopus needs a sudden burst of speed it switches to jet propulsion. To do this they suck water into the mantle cavity and then squirt it at high pressure out of their siphon tube. They do this the same way that they circulate water over their gills, so the octopus is really taking a deep breath and then blowing out hard. The siphon is positioned on the side of the octopus' body, but it can be steered like the engines of a Harrier jet. Sometimes they use it as a boost when walking as well.



The way forward when the octopus needs a quick burst of speed

© Albert Kok

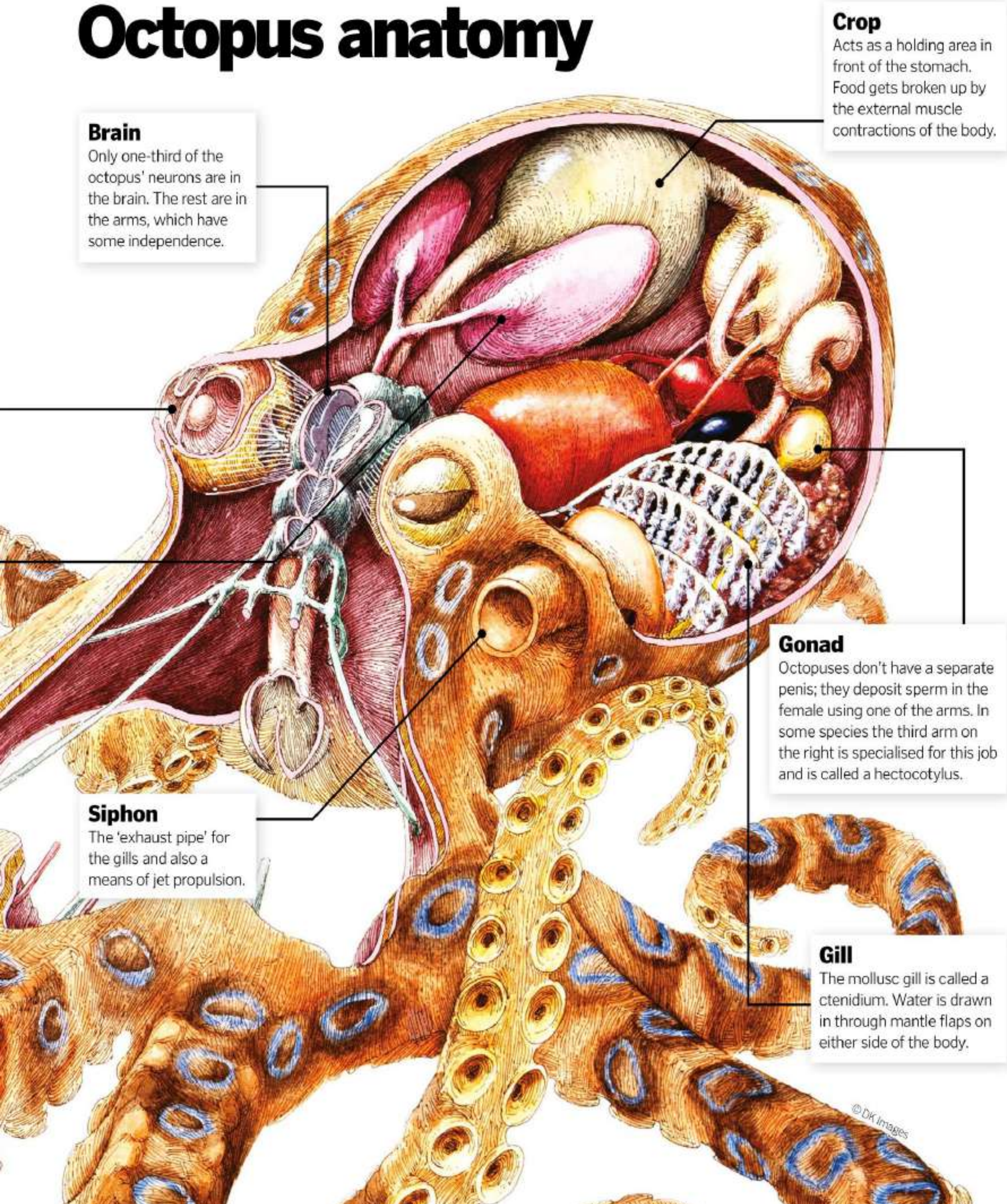


Great for gripping

© Science photo library

DID YOU KNOW? *Octopuses have three hearts: two pump blood through the gills, the third serves the rest of the body*

Octopus anatomy



Brain
Only one-third of the octopus' neurons are in the brain. The rest are in the arms, which have some independence.

Siphon
The 'exhaust pipe' for the gills and also a means of jet propulsion.

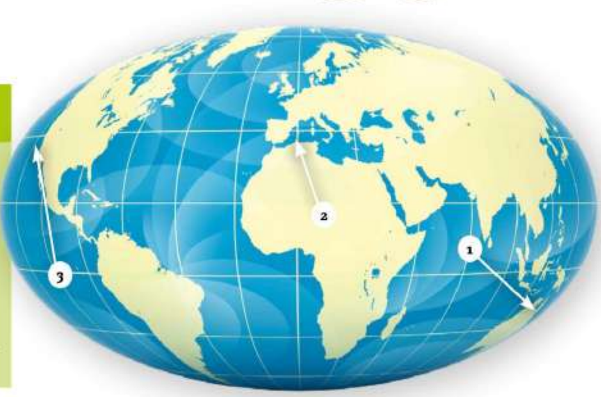
Crop
Acts as a holding area in front of the stomach. Food gets broken up by the external muscle contractions of the body.

Gonad
Octopuses don't have a separate penis; they deposit sperm in the female using one of the arms. In some species the third arm on the right is specialised for this job and is called a hectocotylus.

Gill
The mollusc gill is called a ctenidium. Water is drawn in through mantle flaps on either side of the body.

© DK Images

ON THE MAP



Where can you find an octopus?

1 Coral reefs: The myriad of crevices in a reef are home to lots of tasty creatures, but the octopus is very good at prying them out.

2 Sandy floor: This is more dangerous for an octopus. Some dig burrows in the sand, while others use discarded bivalve shells, like a hermit crab.

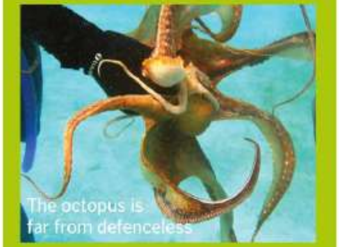
3 Rocky abyss: The North Pacific giant octopus lives in the deep, chilly depths on the Pacific seabed.

Defences

All octopuses inject a paralysing poison through their beak to subdue prey. The smaller the octopus, the more deadly the poison. The ten-centimetre blue-ringed octopus can kill a human.

Octopuses have a lot of predators of their own though, and most of their adaptations are to evade capture. Colour-changing skin cells, called chromatophores, can be used for camouflage or to flash alarming colours to scare predators. Many species also have tiny muscles under the skin to change their texture to resemble spiky coral or fringed seaweed. The mimic octopus will even hold its arms and swim in such a way as to look like a flounder, sea snake or a poisonous lionfish.

If that doesn't work the octopus can squirt a cloud of melanin dye. This provides a smoke screen and also interferes with the sense of smell that most sharks use to locate prey.



The octopus is far from defenceless

Intelligent arms

With the ability to twist in every direction and suckers that can grip and release individually, octopus arms are much too complicated to be controlled from a central brain. Instead they operate semi-autonomously. An octopus issues instructions and trusts that they will be carried out, and occasionally it has a look to make sure. This means that an octopus doesn't have a very good idea of where its arms actually are at any moment and can't work out the shape of something by feeling it, like we can.

Octopuses can taste through their suckers and can detach an arm and regenerate a new one if they need to give you the slip. One species, the paper nautilus, uses an arm to deliver sperm. It detaches and swims across to the female all by itself.

Battle of the NEXT-GEN CONSOLES

Going head to head for a holiday 2020 release, we take a look inside the PlayStation 5 and Xbox Series X

Words by **Scott Dutfield**

© Shutterstock

Over the past 25 years Sony and Microsoft have pushed the boundaries in the latest gaming technology. From the launch of the first PlayStation in 1994 and the first Xbox in 2001, both market-leading companies have driven the narrative when it comes to the future of game design. This winter will see the release of both their latest technological endeavours: the PS5 and Xbox Series X.

With every new console generation that graces the market, new hardware developments are to be expected, and the way these consoles store data is just one of them. Both the Xbox Series X and PlayStation 5 are making huge strides in storage with the introduction of fast solid-state drives (SSD) to replace each of their previous models' hard disk drives (HDD). The SSD stores data, including entire games, which is loaded into the console's random-access memory (RAM) and eventually displayed on your screen when you play. This data transfer is quicker because there are none of the mechanical moving parts seen in a HDD – the data stored on an SSD doesn't become fragmented, which slows read times. For the PS5, data will be read 100-times faster than the PS4. This will mean faster loading times and will transform the way game developers create worlds, allowing ways that were not previously possible.

As Sony and Microsoft prepare to drop the next generation of gaming consoles, we take a look inside the machines and uncover what you may expect to see from both the PS5 and Xbox Series X.

Xbox and PlayStation evolution

How the two consoles have changed over the last 25 years

1994
Sony's PlayStation hits the market. Within ten years this console sold over 100 million units worldwide.

2000
The PlayStation 2 launches, offering high-definition graphics, DVD compatibility and online play.

2001
Microsoft releases the Xbox, packed with a powerful processor and a dedicated hard drive.

DID YOU KNOW? *The PS2 ranks as the best-selling console of all time, with over 157 million units sold worldwide*

> *"Both consoles are making huge strides in storage"*

BETWEEN THE SPECS

PS5		Xbox Series X
Eight-core AMD Zen 2 CPU at 3.5GHz	**Central processing unit (CPU)**	Eight-core AMD Zen 2 CPU at 3.8GHz
10.28 teraflops, 36 control units	**Graphics processing unit (GPU)**	12 teraflops, 52 control units
16 gigabytes	**Memory (RAM)**	16 gigabytes
825 gigabytes (usable)	**Internal storage (SSD)**	1 terabyte
4K ultra-high-definition Blu-ray drive	**Optical drive**	4K ultra-high-definition Blu-ray drive

© Mircosoft

© Microsoft

Microsoft has revealed that the Xbox Series X will support an external one-terabyte removable storage card

2004
Taking the PS2 and making it pocket-sized, Sony creates the PSP: a handheld console that could play games, movies, music and surf the web.

2005
The Xbox 360 is released as the latest in high-definition gaming and online connectivity.

2006
The next console from Sony comes in the form of the PS3, with the addition of Blu-ray compatibility.

2011
Upgrading from the PSP, the PS Vita features a five-inch touch screen, analogue sticks and rear touchpad.

2013
The PS4 hits the shelves with advanced features for online gaming, including integrated streaming and social media functionality.

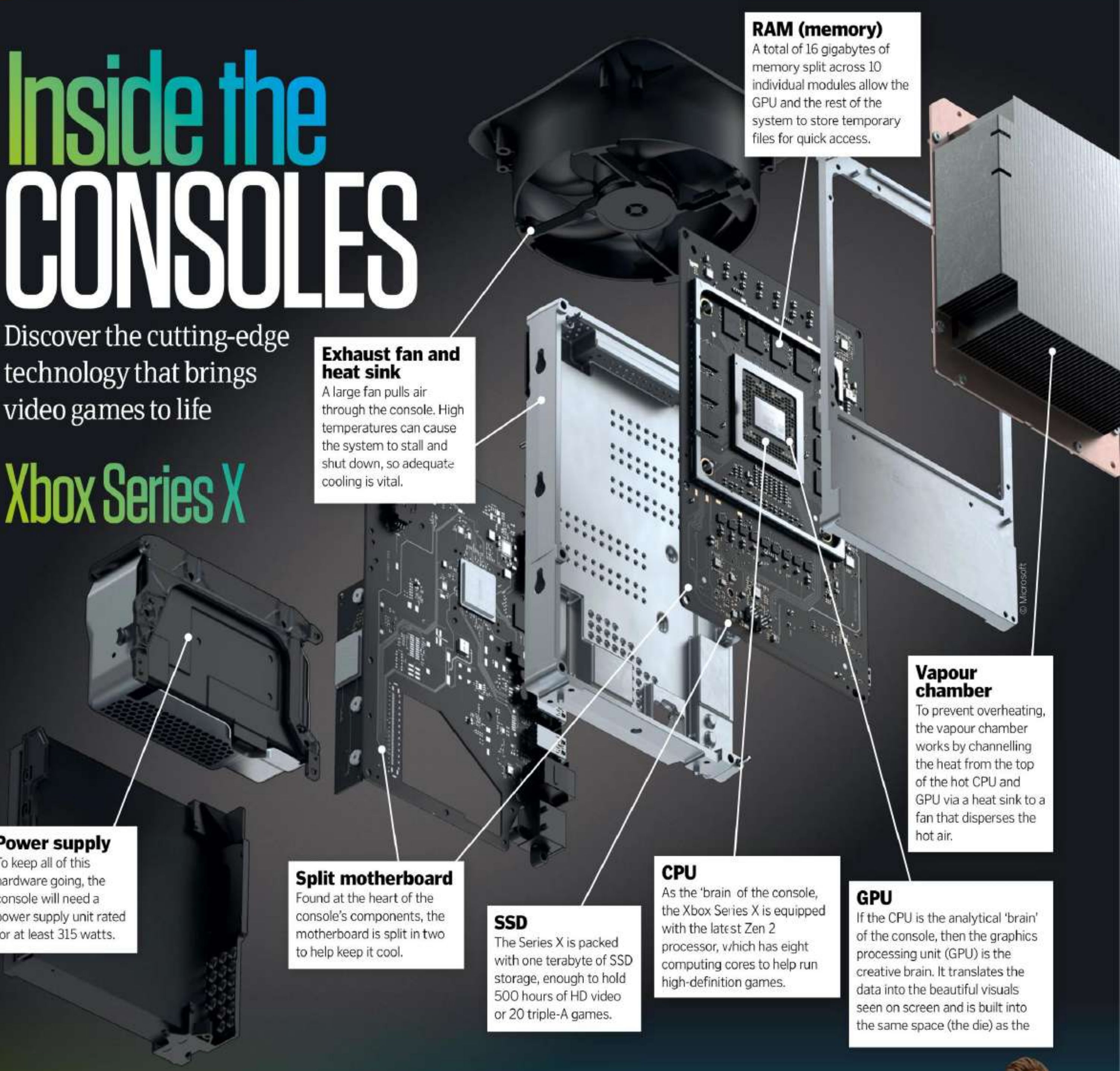
2013
Presenting the possibility of cross-platform PC and console gaming, the Xbox One hits the market.

2020
The Xbox Series X and PlayStation 5 are slated to launch in time for Christmas this year.

Inside the CONSOLES

Discover the cutting-edge technology that brings video games to life

Xbox Series X



RAM (memory)
A total of 16 gigabytes of memory split across 10 individual modules allow the GPU and the rest of the system to store temporary files for quick access.

Exhaust fan and heat sink
A large fan pulls air through the console. High temperatures can cause the system to stall and shut down, so adequate cooling is vital.

Vapour chamber
To prevent overheating, the vapour chamber works by channelling the heat from the top of the hot CPU and GPU via a heat sink to a fan that disperses the hot air.

Power supply
To keep all of this hardware going, the console will need a power supply unit rated for at least 315 watts.

Split motherboard
Found at the heart of the console's components, the motherboard is split in two to help keep it cool.

SSD
The Series X is packed with one terabyte of SSD storage, enough to hold 500 hours of HD video or 20 triple-A games.

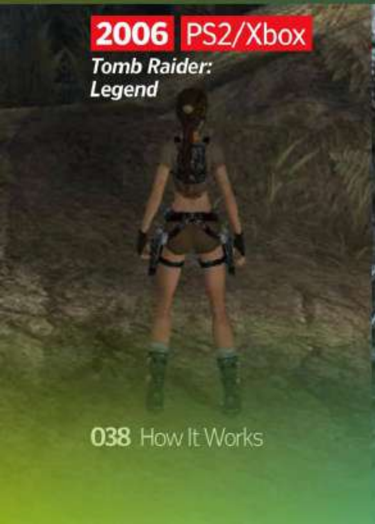
CPU
As the 'brain' of the console, the Xbox Series X is equipped with the latest Zen 2 processor, which has eight computing cores to help run high-definition games.

GPU
If the CPU is the analytical 'brain' of the console, then the graphics processing unit (GPU) is the creative brain. It translates the data into the beautiful visuals seen on screen and is built into the same space (the die) as the

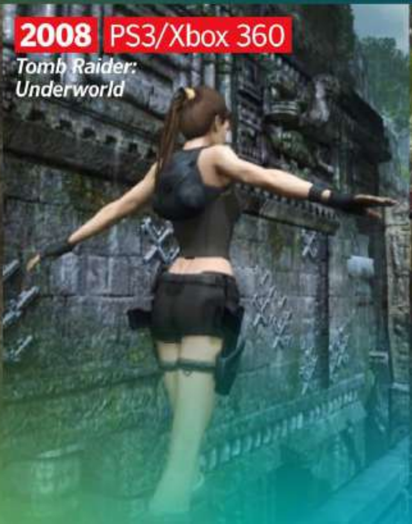
© Microsoft

Graphical evolution

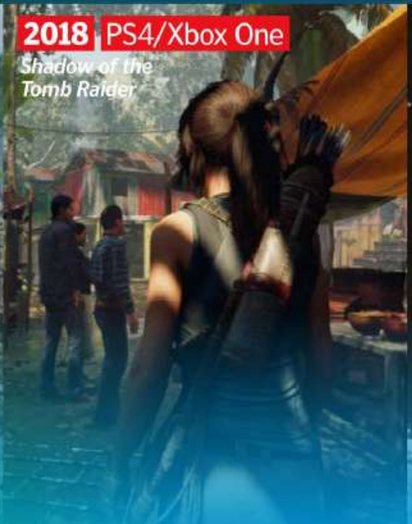
How the visuals of perennial classic *Tomb Raider* have improved with new graphics technology



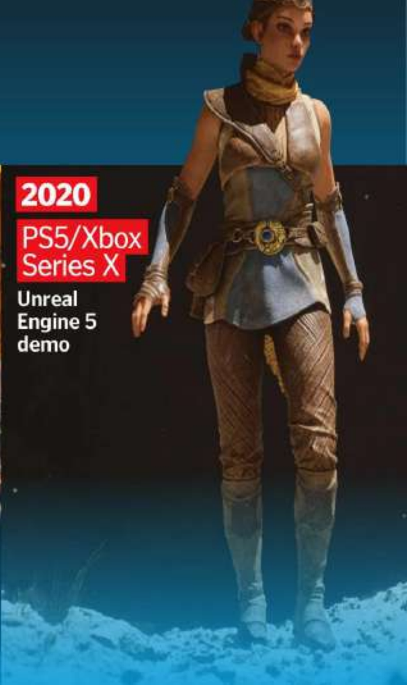
2006 PS2/Xbox
Tomb Raider: Legend



2008 PS3/Xbox 360
Tomb Raider: Underworld



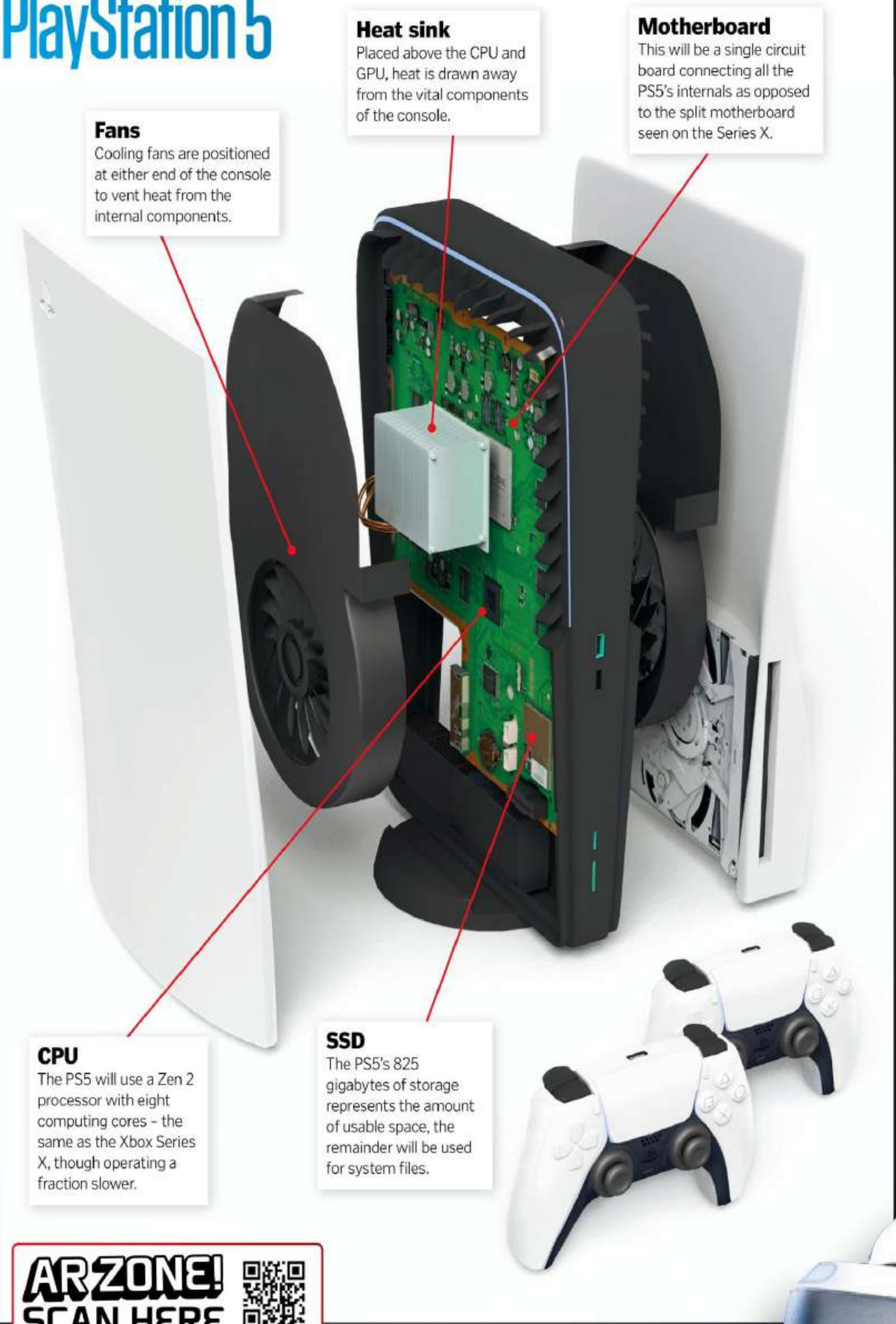
2018 PS4/Xbox One
Shadow of the Tomb Raider



2020 PS5/Xbox Series X
Unreal Engine 5 demo

DID YOU KNOW? *The Xbox One Live platform runs off more than 300,000 servers*

PlayStation 5



Heat sink
Placed above the CPU and GPU, heat is drawn away from the vital components of the console.

Motherboard
This will be a single circuit board connecting all the PS5's internals as opposed to the split motherboard seen on the Series X.

Fans
Cooling fans are positioned at either end of the console to vent heat from the internal components.

CPU
The PS5 will use a Zen 2 processor with eight computing cores – the same as the Xbox Series X, though operating a fraction slower.

SSD
The PS5's 825 gigabytes of storage represents the amount of usable space, the remainder will be used for system files.

© Illustration by Adrian Mann

AR ZONE! SCAN HERE

5 FACTS ABOUT PLAYSTATION AND XBOX

1 Nintendo almost owned PlayStation
Originally the PlayStation was developed as a CD-ROM add-on for Nintendo's Super Famicom, the Japanese name for the SNES. Nintendo pulled out of the deal with Sony, who decided to release its own disc-based console.

2 Green was the only option
It's been reported that the reason that Xbox's iconic X logo is green is because the designer, Horace Luke, only had a green-coloured marker after all his other markers were stolen.

3 Towers of data
If you remember the loading screen of the PS2, you might recall a series of towers shooting up and down. This wasn't just a fun graphic – they represented the saved game data. More towers meant more data was stored.

4 Overseas slump
The first Xbox only sold 123,000 units in its first week of release in Japan in 2002. Microsoft slashed the price of the Xbox from $299 to $199 only two months after release to boost sales, barely making a profit in the process.

5 PlayStation played CDs
Not only was it a revolutionary console for the 1990s, but the first PlayStation was also a music CD player. Some PS1 games would double as a music disc, playing tracks from the games on conventional CD players.

A new virtual world

One rapidly growing avenue in gaming has been virtual reality (VR). PlayStation gave gamers the option to enter new worlds with its own PSVR headset back in 2016, whereas Microsoft cancelled its VR hardware for the Xbox One. There were rumours that the Xbox Series X might change that, though Xbox head Phil Spencer put those rumours to rest when he spoke on a Gamertag Radio podcast, saying there were no plans for any sort of VR on the Xbox Series X. Sony, on the other hand, likely has new PSVR technology in development, thought to work exclusively with the PS5.

Achieving the liquid chocolate's smooth consistency is a lengthy process

How is chocolate made?

From the tree to your mouth, we reveal the secrets of the chocolate factory

© Getty

Chocolate production begins at the cocoa tree, where cocoa pods containing cocoa beans in a cotton wool-like pulp are harvested between the months of October and December. The beans are placed between layers of banana leaves for six days to drain the pulp away – a method known as 'heap' – before being dried in sunlight, packaged and sent to a factory for chocolate making.

Inside a chocolate factory the beans are heated inside a continuous roaster as they travel along a conveyor belt. The timing of this process varies depending on the flavour required. Once suitably roasted they are broken down into small pieces and their brittle shells are removed, leaving only their meaty centres, the 'nibs', which contain the cocoa butter essential for chocolate production. A mill grinds these nibs into a thick, brown liquid known as 'cocoa liquor', the basis of all chocolate products, which is then mixed with varying amounts of sugar and milk depending on the required type of chocolate. Typically dark chocolate consists of 70 per cent cocoa liquor, while milk and white chocolate have 30 per cent.

Vacuum ovens then dry this mixture into what is known as a chocolate 'crumb' before giant rollers squash the liquor together. It is then ground between rollers to improve the silky texture before being smoothed even further in a process known as 'conching'. This involves kneading the mixture in giant tanks heated to about 46 degrees Celsius, with the very best chocolate being conched for more than a week. The final process is tempering, where the liquid is continuously cooled and heated in a cycle until it is a stable chocolatey consistency.

After this final stage of the chocolate-making process the liquid can be poured into moulds, cooled and wrapped at high speeds to make products like bars of chocolate. To make chocolate with a particular filling, such as caramel, the insides of the bars pass along a conveyor belt and are 'enrobed' by the liquid chocolate before being cooled and wrapped.

© Cadbury

© Cadbury

The custom of giving an egg at Easter has its origins in paganism

© Cadbury

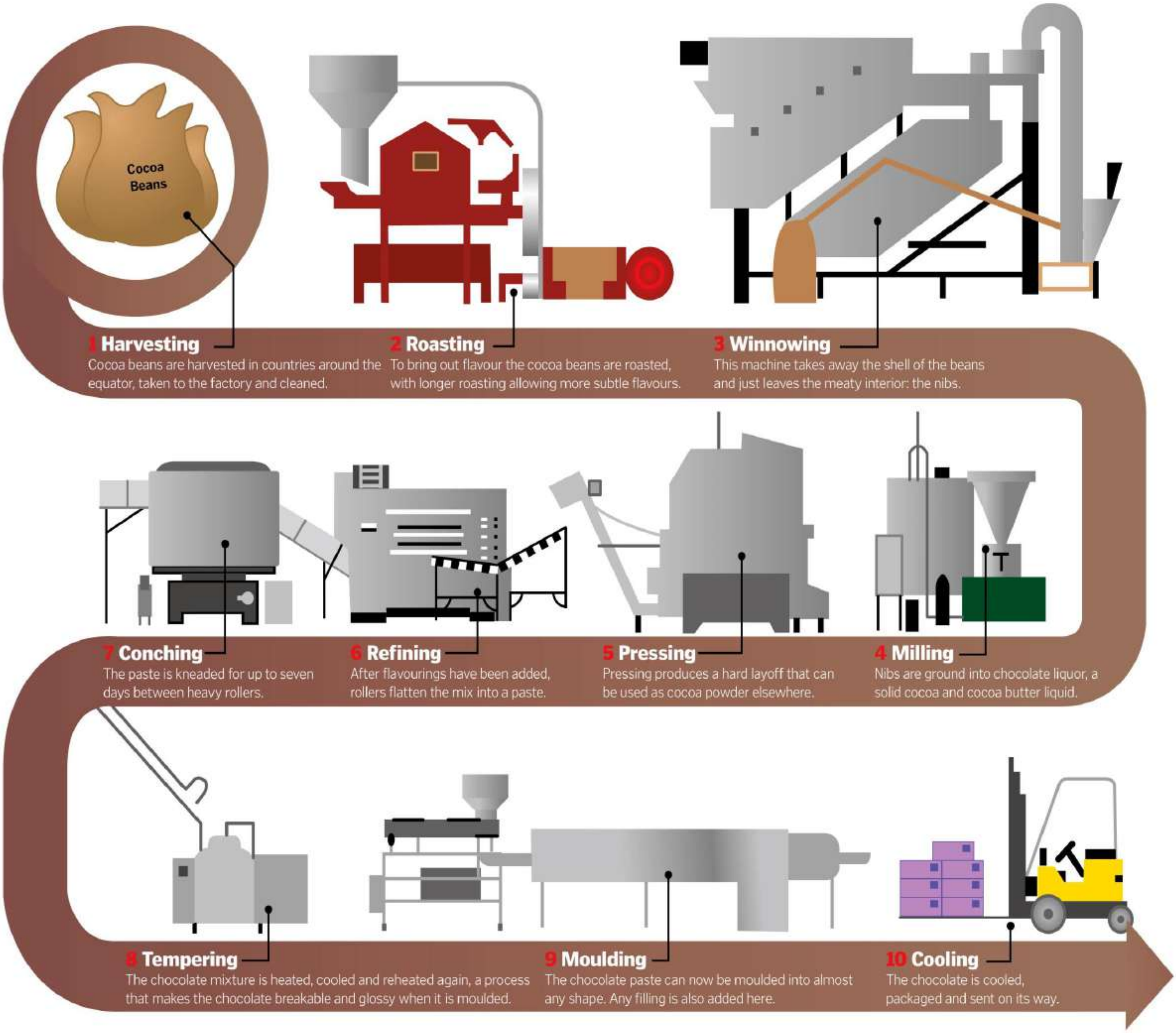
Giant tanks store liquid chocolate at 46°C

© Cadbury

DID YOU KNOW? *It takes a whole year's crop from one tree to make 450 grams of cocoa*

It's crafty at the chocolate factory

From bean to bar, how does chocolate make its way to your mouth?



1 Harvesting

Cocoa beans are harvested in countries around the equator, taken to the factory and cleaned.

2 Roasting

To bring out flavour the cocoa beans are roasted, with longer roasting allowing more subtle flavours.

3 Winnowing

This machine takes away the shell of the beans and just leaves the meaty interior: the nibs.

4 Milling

Nibs are ground into chocolate liquor, a solid cocoa and cocoa butter liquid.

5 Pressing

Pressing produces a hard layoff that can be used as cocoa powder elsewhere.

6 Refining

After flavourings have been added, rollers flatten the mix into a paste.

7 Conching

The paste is kneaded for up to seven days between heavy rollers.

8 Tempering

The chocolate mixture is heated, cooled and reheated again, a process that makes the chocolate breakable and glossy when it is moulded.

9 Moulding

The chocolate paste can now be moulded into almost any shape. Any filling is also added here.

10 Cooling

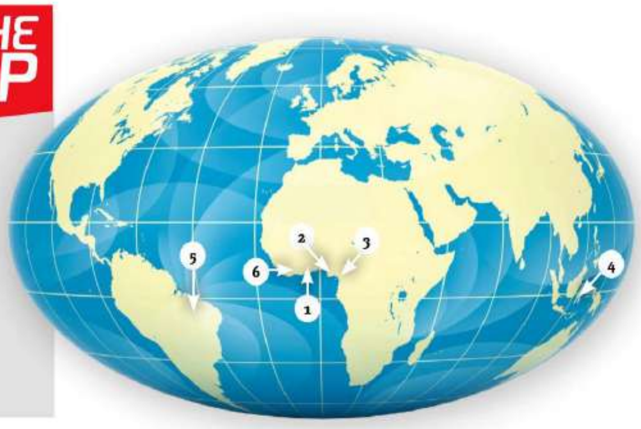
The chocolate is cooled, packaged and sent on its way.

ON THE MAP

Top six cocoa bean growers

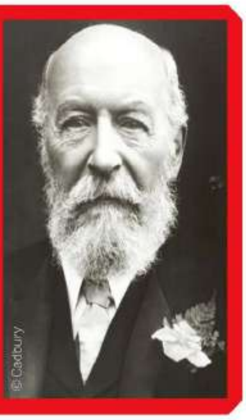
Only areas within 20 degrees of the equator can grow cocoa beans:

1 Ghana
2 Nigeria
3 Cameroon
4 Indonesia
5 Brazil
6 Ivory Coast



George Cadbury

In the 1830s John Cadbury started a small but not especially successful chocolate factory. Later his sons were to revitalise their father's failing empire. George built the factory town of Bournville – also the name of a dark chocolate Cadbury product – for its employees in the process.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Mummies unwrapped

Discover the wonder of Egyptian mummification as we unravel the secrets of these carefully preserved corpses

Mummification was an embalming process undertaken by the ancient Egyptians. They believed that by preserving a body, its soul could live on in the afterlife. Embalmers offered various packages, which included a basic, standard and luxury version. Even so, it was only the rich that could afford to mummify their dead and thereafter place them in an elaborate tomb. Ordinary civilians were buried in pit graves, and some of these bodies were naturally dried.

Mummification was an elaborate and lengthy process that took 70 days. Violation of the body was abhorred, however, so the first incision performed on the corpse was made by a 'scapegoat', who was then ritually stoned and chased from the embalming chamber.

Afterwards the intestines, lungs, stomach and liver were removed – these were mummified and placed in special containers called canopic jars. The brain was pulverised with a long, narrow instrument and drained through the nose or the back of the skull. The heart, which was then known as the seat of learning, was left inside the body. During the mummification process the priests would venerate the dead; they would light incense, recite prayers and invoke aid and protection from ancient Egyptian gods. Once cleansed, the body was then ready to be dried.

The ancient Egyptians placed the body in natron salts, which absorbed all its moisture. After a period of 40 days it was removed and packed with herbs, oils and spices, which were known to cleanse and preserve the cavities. If extra body parts were needed the corpse was equipped with false wooden limbs, or eyes made of obsidian. It was then ready for bandaging. Each limb was carefully tended to. Fingers and toes were treated individually, and golden caps were placed on the nails. In order to protect it, a large number of amulets were left on specific parts of the body. Often garlands of leaves or berries, which were thought to have rejuvenating properties, were placed around the neck. The hair was dressed with oils and jewellery. Due to heat and lice the ancient Egyptians shaved their heads, so elaborate wigs – which were made of human hair – were placed on the deceased. Make-up was applied, and the body was dressed in fine clothes and adornments. While women were buried with combs and pottery, men were armed with daggers or swords. These were placed either on the body or within the wrappings.

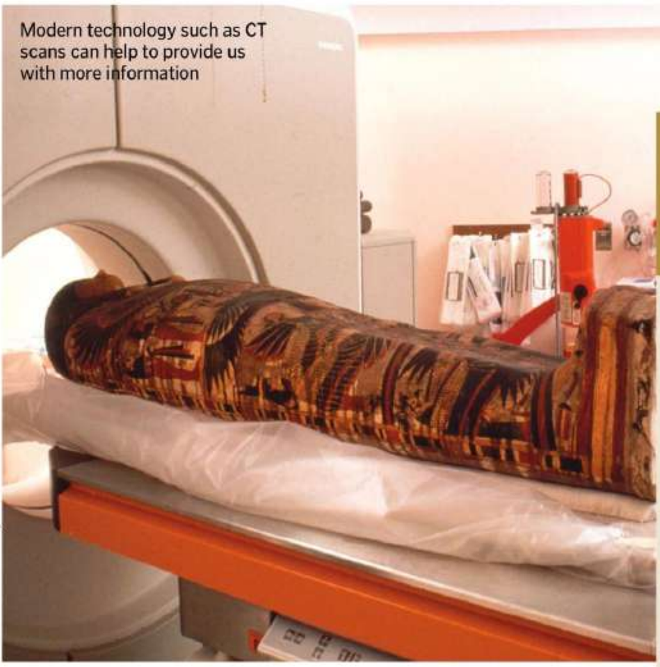
At the beginning of the 20th century, Egyptology was in its infancy. Many early excavators ignored human remains. The first archaeologists were more interested in treasure than mummies, and even the body of Tutankhamun was subjected to trauma. Although Howard Carter was a brilliant excavator, he couldn't have imagined the

© Science Photo Library

wonders that the dead could reveal. Nor did he envisage that innovations in science would enable us to make important new discoveries about ancient Egyptian mummies. Despite this, the world was now fascinated. In Victorian times the unwrapping of an Egyptian mummy – which often took place in affluent drawing rooms – would be followed by tea, cake and polite conversation.

Thankfully times have changed, and the first scientific unwrapping of a mummy took place in Manchester when Margaret Murray examined the two brothers, Khnum-Nakht and Nekht-Ankh, in 1908. Manchester continues its strong association with the scientific study of mummies. It is here that Professor Rosalie David conducted many innovative investigations into ancient diseases. In 1979 she established the International Mummy Database, which employs endoscopy and serological studies, X-ray examinations and MRI scans. Perhaps the most important investigation into ancient mummies was undertaken in Paris between 1976 and 1977, when the mummy of Ramesses II was met at Orly Airport and treated like a visiting head of state. A team of over 100 scientists, including botanists, microbiologists and anthropologists, worked on his body and published startling new evidence about mummification techniques.

Examinations that employ DNA sampling are now used in mummy studies. While the practice is still limited, it can enable Egyptologists to identify, establish and study family groups. We are now able to shed light on the everyday life of the ancient Egyptians, going on to analyse dental hygiene, hair dyes and make-up. When examining mummies we are now able to study textiles, jewellery, oils and even head lice – the oldest 'nits' in the world were found on a Manchester mummy. From these examinations we can learn a great deal about the diseases, afflictions and the general aches and pains of all classes of people, and we can even identify trauma wounds, arthritis and polio. With the invention of new scanning techniques, the destructive process of 'unwrapping' a mummy is now a thing of the past. What remains constant, however, is that mummies continue to fascinate, excite and inspire us.


Modern technology such as CT scans can help to provide us with more information

© Science Photo Library

> "Only the rich could afford to mummify their dead and place them in an elaborate tomb"

The well-preserved, naturally mummified body of a figure known as the 'Tollund Man'

King Tutankhamun, discovered by Howard Carter in 1922

TYPES OF... MUMMIES AROUND THE WORLD

1 Ice mummies

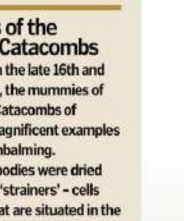
Dated to Pazyryk culture, the Siberian Ice Maiden and her contemporaries were buried in the 5th century BCE. These mummies were buried with elaborate funerary equipment – in the case of the Ice Maiden there were six horses and a symbolic last meal. Her body is covered in a series of beautiful tattoos depicting mythical animals.

2 Mummies of the Canary Islands

The Guanche mummies were found on the Canary Islands in the 15th century, when they were discovered by Spanish invaders. Little is known about them – many were pulverised and used as medicinal powders. Dried in the Sun, the mummies were packed with sand and wrapped in animal skins. They were then placed on mummy boards and left in caves.

3 Inca mummies

Inca mummies, found in Peru and Chile, are approximately 500 years old. The remains are those of young children sacrificed on the mountains of the Andes in order to honour the gods. Other mummies include those known as the Chachapoyas, which are found in northern Peru. These mummies were mummified in the driest areas of the jungle.



4 Mummies of the Capuchin Catacombs

Dated between the late 16th and 20th centuries, the mummies of the Capuchin Catacombs of Palermo are magnificent examples of the art of embalming. Thousands of bodies were dried here in 'strainers' – cells that are situated in the passageways of the catacombs. After eight months they were removed and soaked in vinegar. Adults and children are placed on display in coffins, niches and on the walls.

TYPES OF…
NATURAL MUMMIES

1 Bog bodies
Waterlogged peat holds very little oxygen, and this means that the microorganisms that cause decomposition cannot survive. The acidity in the bog, along with sphagnum moss, also helps to preserve the body. While the skin, hair and internal organs are remarkably well preserved, the bones are softened. The body also begins to take on a dark, leathery appearance.

2 Self-mummification
Self-mummification was practised by the Sokushinbutsu, a group of Japanese Buddhist monks. For several years the monks would live on a diet of seeds and nuts and would drink the sap of the urushi tree, which would cause vomiting and loss of body mass. They would seal themselves in a tomb and die – if the body had mummified, it was regarded as a holy vessel.

3 Desiccation
When left in the open, water, insects and heat will rapidly destroy the body. If the body is buried in sand or salt, moisture in the flesh is absorbed and the corpse is preserved. More importantly, in the case of Egyptian mummies the removal of internal organs aids this process, preventing internal bloating and decay.

4 Ice mummies
Ice prevents decomposition of the body and inhibits the growth of bacteria. It also preserves pollen and dust grains. Ice is an excellent and effective agent, so ice mummies seem very lifelike. Their hair, eyelashes and body decorations are often astounding. Ice mummies have even been discovered with votive offerings and grave goods.

Ötzi the Iceman is a famous natural ice mummy

© South Tyrol Museum of Archaeology

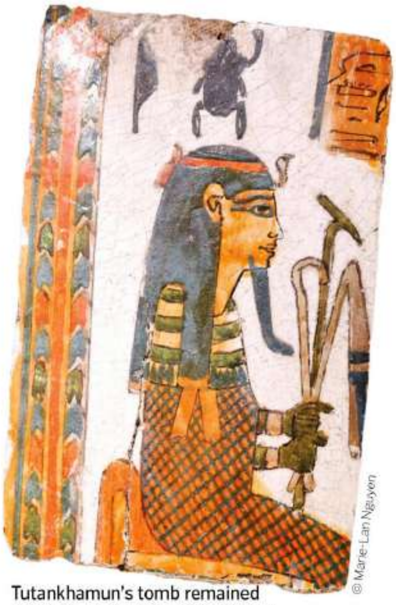
Death chamber

We open the doors to the eerie and mysterious world of the embalming chamber to explain exactly how the process was performed

Although the House of the Dead was occupied by priests and their servants, it was also regarded as a place of dread. The sight or smell of the embalming chamber was a source of fear and repulsion.

Inside the House of the Dead there would often be a long queue of bodies waiting to be embalmed; they would be placed on sloping beds so that bodily fluids and blood would drain into vats. Insects, inexperienced workers and the heat could make the work difficult. The embalming process was an urgent and bloody activity – when rushed the embalmers often lost or severed limbs.

The morality of the morticians was also regarded with suspicion; they were often associated with robbery and corruption. However, morticians were also viewed as mystics and magicians, and a sense of secrecy surrounded their art of preparing the dead.



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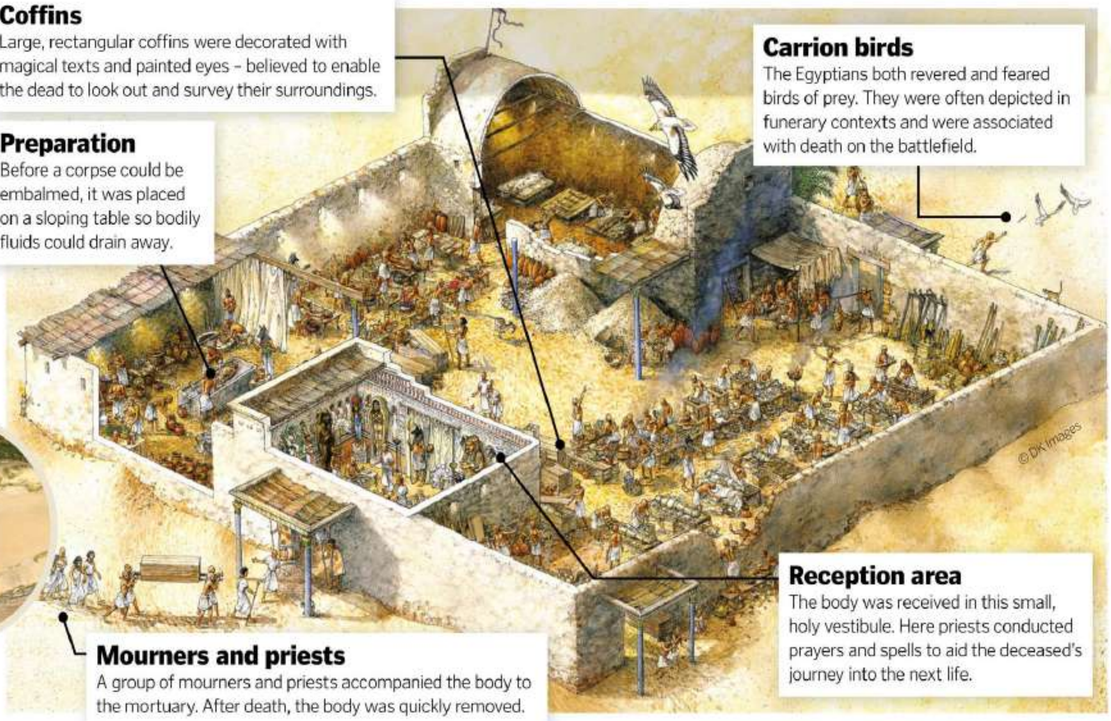
Tutankhamun's tomb remained sealed for more than 3,200 years



Coffins
Large, rectangular coffins were decorated with magical texts and painted eyes – believed to enable the dead to look out and survey their surroundings.

Preparation
Before a corpse could be embalmed, it was placed on a sloping table so bodily fluids could drain away.

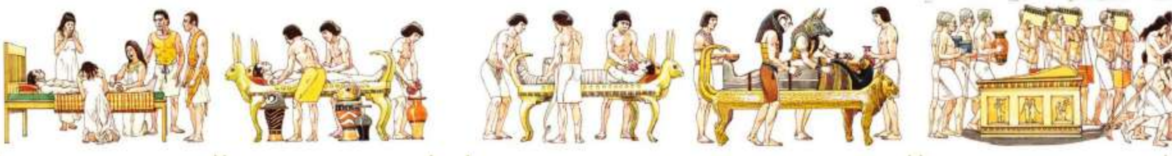
Carrion birds
The Egyptians both revered and feared birds of prey. They were often depicted in funerary contexts and were associated with death on the battlefield.

Reception area
The body was received in this small, holy vestibule. Here priests conducted prayers and spells to aid the deceased's journey into the next life.

Mourners and priests
A group of mourners and priests accompanied the body to the mortuary. After death, the body was quickly removed.

© DK Images

FROM DEATH TO THE TOMBS



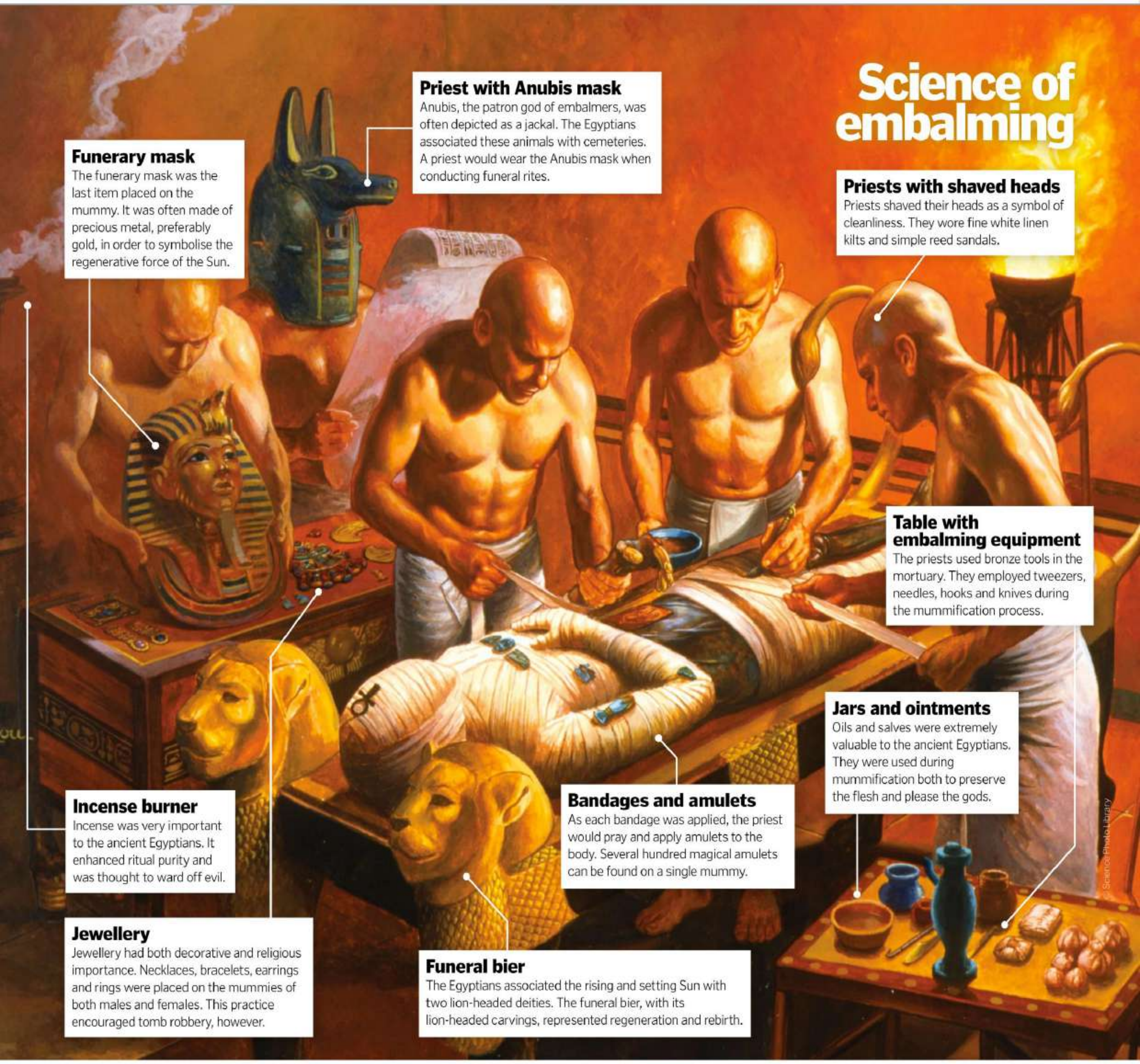
1. The death scene
This bed is a traditional funeral bier, or stand, which can be found among ancient Egyptian funerary equipment. It was designed to represent the body of a lion.

2. Embalmers at work
Several priests attended the body of the deceased; while some worked on the body, others would recite prayers and perform magical incantations.

3. Bandaging and anointing
Metres of linen bandages were used on mummies, where even each finger and toe was wrapped individually. The body was anointed in protective oils and resins.

4. Placement in coffin
Coffins differed over the years, both in style and decoration. The coffin was made of wood and gilded with precious metals. It was inscribed with magical texts.

Science of embalming



Priest with Anubis mask
Anubis, the patron god of embalmers, was often depicted as a jackal. The Egyptians associated these animals with cemeteries. A priest would wear the Anubis mask when conducting funeral rites.

Funerary mask
The funerary mask was the last item placed on the mummy. It was often made of precious metal, preferably gold, in order to symbolise the regenerative force of the Sun.

Priests with shaved heads
Priests shaved their heads as a symbol of cleanliness. They wore fine white linen kilts and simple reed sandals.

Table with embalming equipment
The priests used bronze tools in the mortuary. They employed tweezers, needles, hooks and knives during the mummification process.

Jars and ointments
Oils and salves were extremely valuable to the ancient Egyptians. They were used during mummification both to preserve the flesh and please the gods.

Incense burner
Incense was very important to the ancient Egyptians. It enhanced ritual purity and was thought to ward off evil.

Bandages and amulets
As each bandage was applied, the priest would pray and apply amulets to the body. Several hundred magical amulets can be found on a single mummy.

Jewellery
Jewellery had both decorative and religious importance. Necklaces, bracelets, earrings and rings were placed on the mummies of both males and females. This practice encouraged tomb robbery, however.

Funeral bier
The Egyptians associated the rising and setting Sun with two lion-headed deities. The funeral bier, with its lion-headed carvings, represented regeneration and rebirth.

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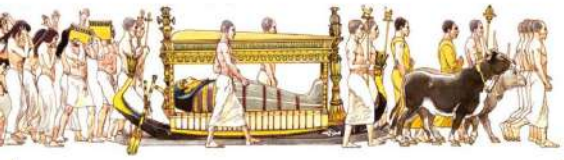
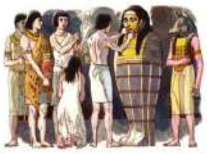
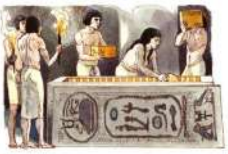
A step-by-step look at the mummification process, from deathbed to the grandeur of the tomb



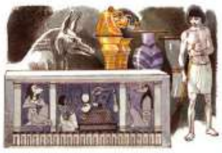
5. Mourners
The coffin was placed on a bier and dragged by oxen to the tomb. It was accompanied by priests, mourners and relatives.



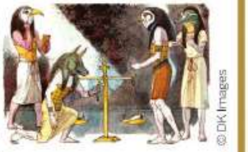
6. Opening of the mouth
A priest, dressed in leopard skin, would 'open the mouth' of the deceased with an instrument called an adze. This allowed the spirit to fly free from the body.



7. Placing goods in the tomb
The ancient Egyptians believed that you could indeed 'take it with you'. Their tombs were filled with goods that were needed in the next world.



8. Priest leaving the tomb
At the culmination of the funerary rituals, the priest would leave the tomb. As he retreated, he would sweep away his footsteps from the dust.



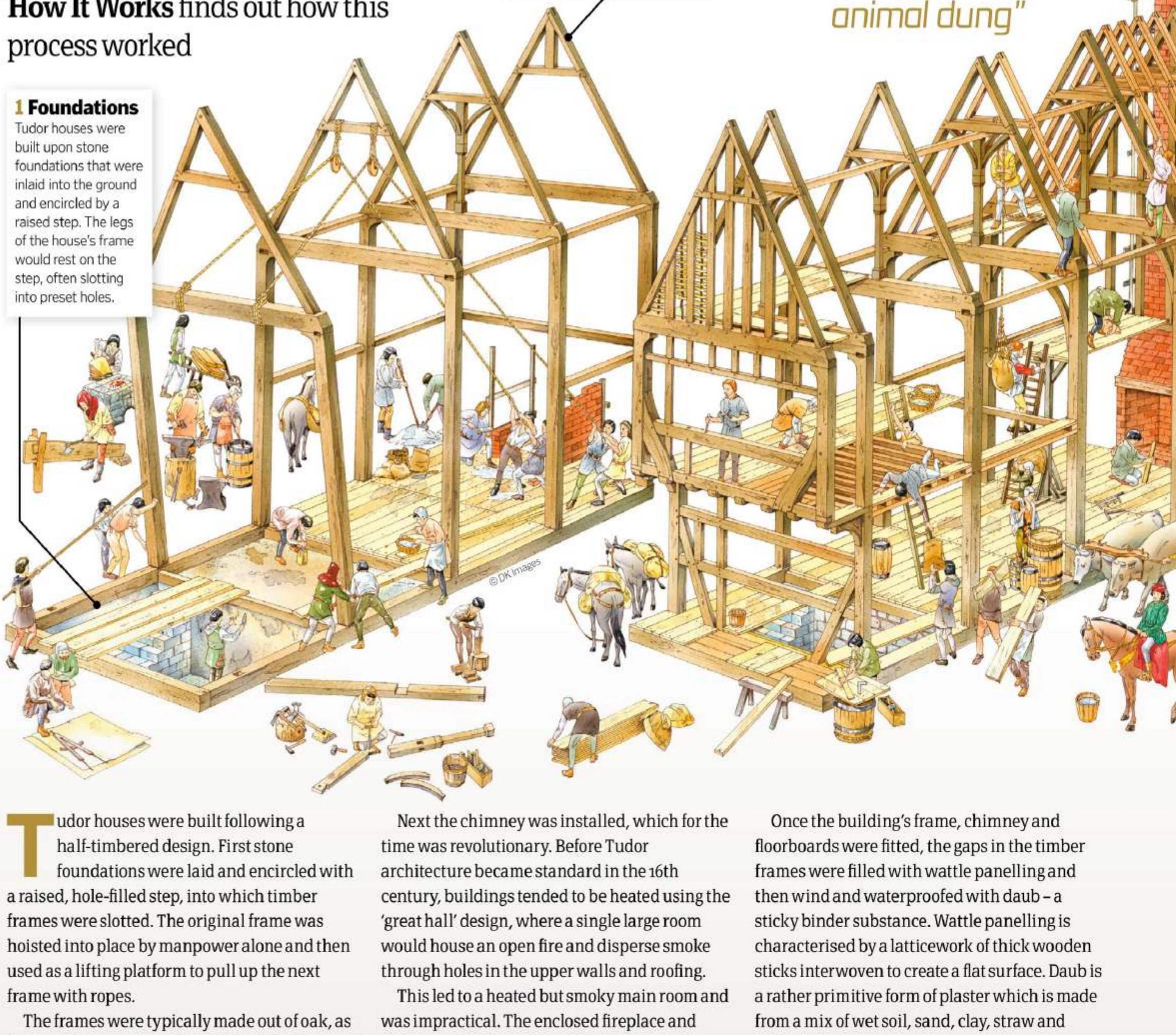
9. Weighing of the heart
The heart is weighed before Osiris, god of the dead. If found wanting, the deceased would be devoured by a crocodile-headed monster.

© DK Images

Tudor houses

Despite retaining the medieval taste for a Gothic style, the Tudors drove change in how houses were constructed through the late 15th and 16th centuries. **How It Works** finds out how this process worked

> "Daub is a primitive form of plaster made from a mix of wet soil, sand, clay, straw and animal dung"



2 Frame
Frames in Tudor houses were built out of wood in what is now referred to as a half-frame design. Oak tended to be the wood of choice due to its prolificacy in Britain and its good strength.

1 Foundations
Tudor houses were built upon stone foundations that were inlaid into the ground and encircled by a raised step. The legs of the house's frame would rest on the step, often slotting into preset holes.

Tudor houses were built following a half-timbered design. First stone foundations were laid and encircled with a raised, hole-filled step, into which timber frames were slotted. The original frame was hoisted into place by manpower alone and then used as a lifting platform to pull up the next frame with ropes.

The frames were typically made out of oak, as the wood was common in Britain at the time and strong considering how easy it was to cut by hand. Due to the beams being cut by the hands of carpenters, they were often rather uneven and – as can be seen today – this led to a slightly bumpy, off-kilter finish.

Next the chimney was installed, which for the time was revolutionary. Before Tudor architecture became standard in the 16th century, buildings tended to be heated using the 'great hall' design, where a single large room would house an open fire and disperse smoke through holes in the upper walls and roofing.

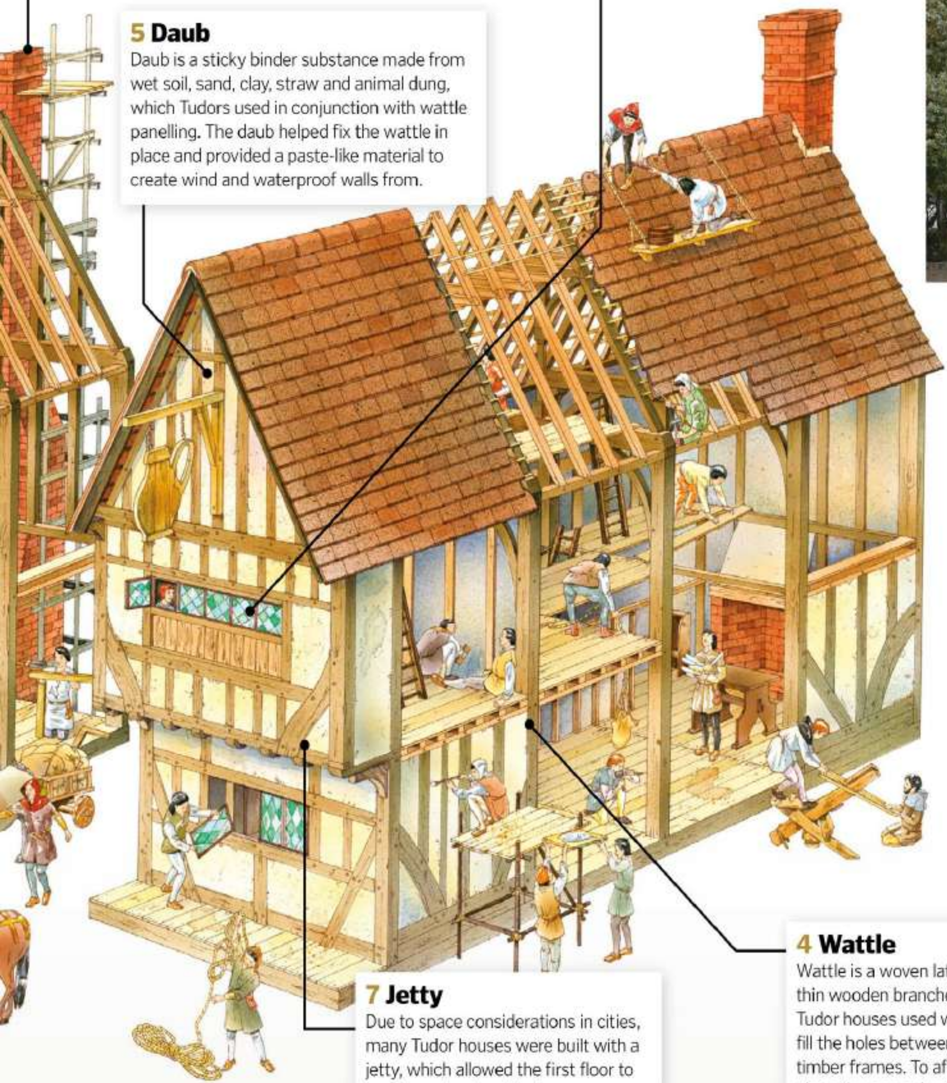
This led to a heated but smoky main room and was impractical. The enclosed fireplace and chimney structure allowed Tudor houses to disperse smoke efficiently, allowing for smaller rooms to be heated. During this stage the first floor was boarded and stairs were installed, both made from wood, and the jetty support beams were prepared.

Once the building's frame, chimney and floorboards were fitted, the gaps in the timber frames were filled with wattle panelling and then wind and waterproofed with daub – a sticky binder substance. Wattle panelling is characterised by a latticework of thick wooden sticks interwoven to create a flat surface. Daub is a rather primitive form of plaster which is made from a mix of wet soil, sand, clay, straw and animal dung.

When combined these completed the walls of a Tudor house. The building was then roofed, either in thatch – which was common for secular buildings at the time – or crudely tiled, as well as having its windows installed. Glass creation in

DID YOU KNOW? *The Victorians coated Tudor houses' wooden beams with tar to make them waterproof*

Building a Tudor house



3 Chimney
Replacing the medieval great hall system of dispersing smoke, Tudor houses introduced enclosed fireplaces and chimneys to channel the fire's smoke out of the building.

5 Daub
Daub is a sticky binder substance made from wet soil, sand, clay, straw and animal dung, which Tudors used in conjunction with wattle panelling. The daub helped fix the wattle in place and provided a paste-like material to create wind and waterproof walls from.

6 Windows
As glass was still in its infancy as a material, large panes could not be created for Tudor houses. To create windows, multiple smaller pieces were held together with lead lattices and supported by dedicated wooden beams. Window frames were also made from wood.

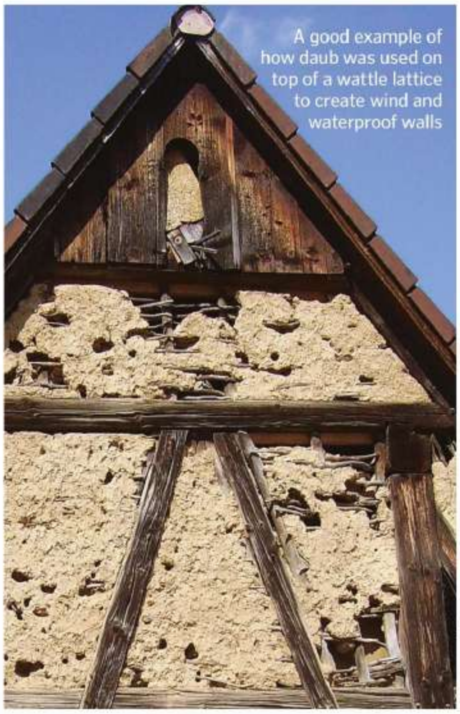
4 Wattle
Wattle is a woven lattice of thin wooden branches. Tudor houses used wattle to fill the holes between the timber frames. To affix it in place it was used with daub.

7 Jetty
Due to space considerations in cities, many Tudor houses were built with a jetty, which allowed the first floor to overhang the street below.

the Tudor period was primitive compared to today's modern standards, and craftsmen were unable to create the necessary large single panes. Tudor windows were therefore constructed from numerous smaller panes which were held together in place by an iron latticework in a tall, thin frame. Due to the combined weight of the iron lattice and thick glass, the wooden window frames needed to be supported by a dedicated wooden beam which was positioned underneath.

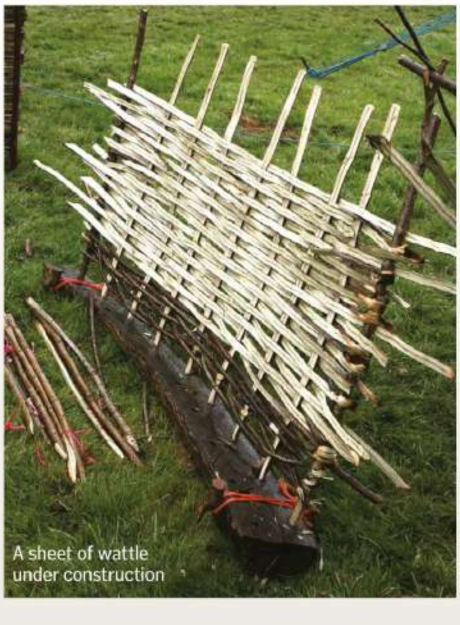
Finally the external trim and decorations were completed, which due to the influence of the renaissance on 16th-century Britain led to big changes in artwork, carvings, doors and also window frames. A good example of these changes can be seen in the oriel; this is an overhung, multi-sided window cantilevered out from either the building's first or second floor. Daub tended to be coated in an ochre-coloured pigment, while the wooden beams of the building remained exposed.

The archetypal tar-black beams and whitewashed daub were not actually widespread during the Tudor period itself, but more a product of a movement of Victorian romanticisation of the Tudor period later in the 19th century, with many traditional and mock houses being repainted to give them the effect we often see on those that remain today.



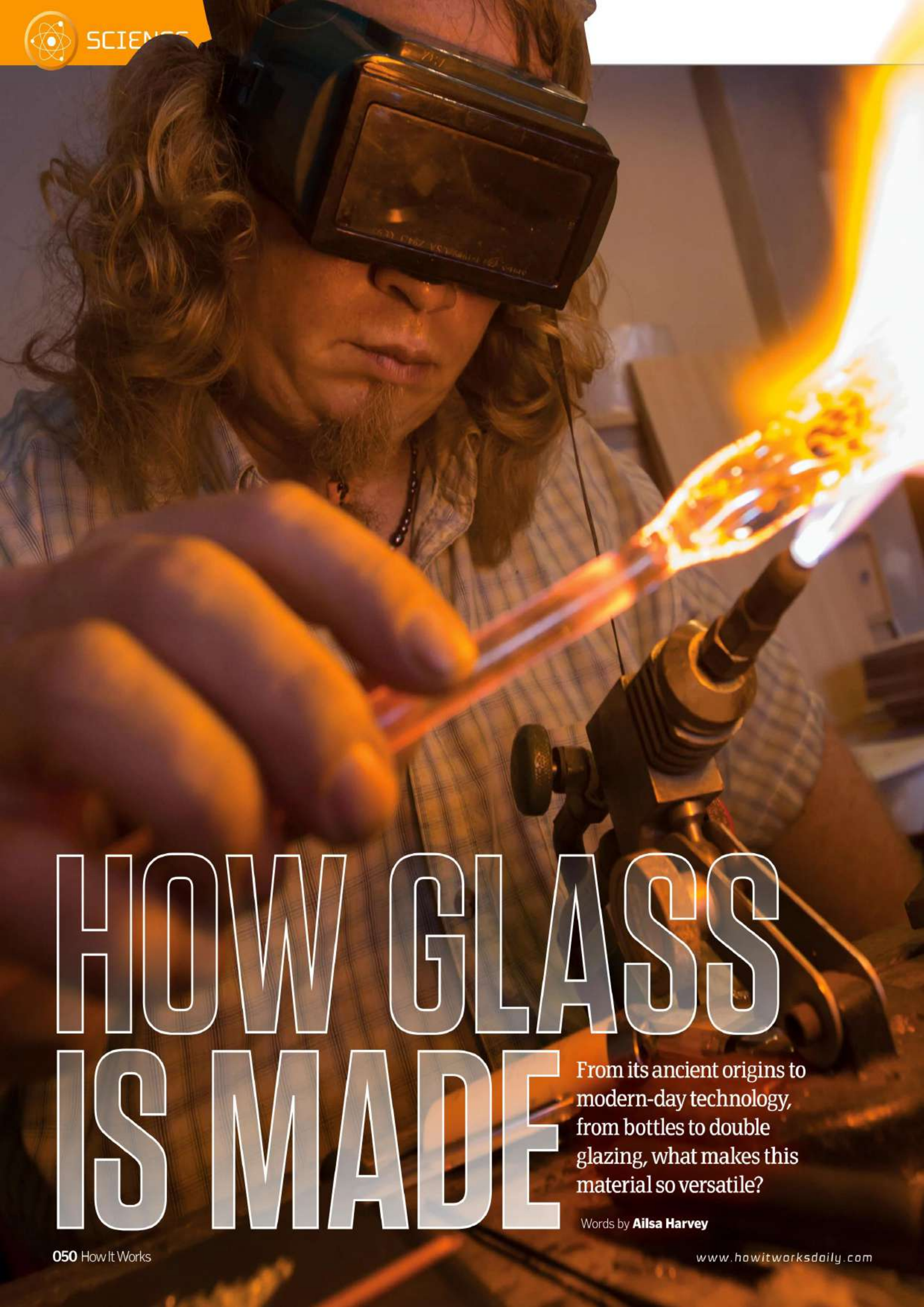
A good example of how daub was used on top of a wattle lattice to create wind and waterproof walls

© Immanuel Giel



A sheet of wattle under construction

© Richard New Forest



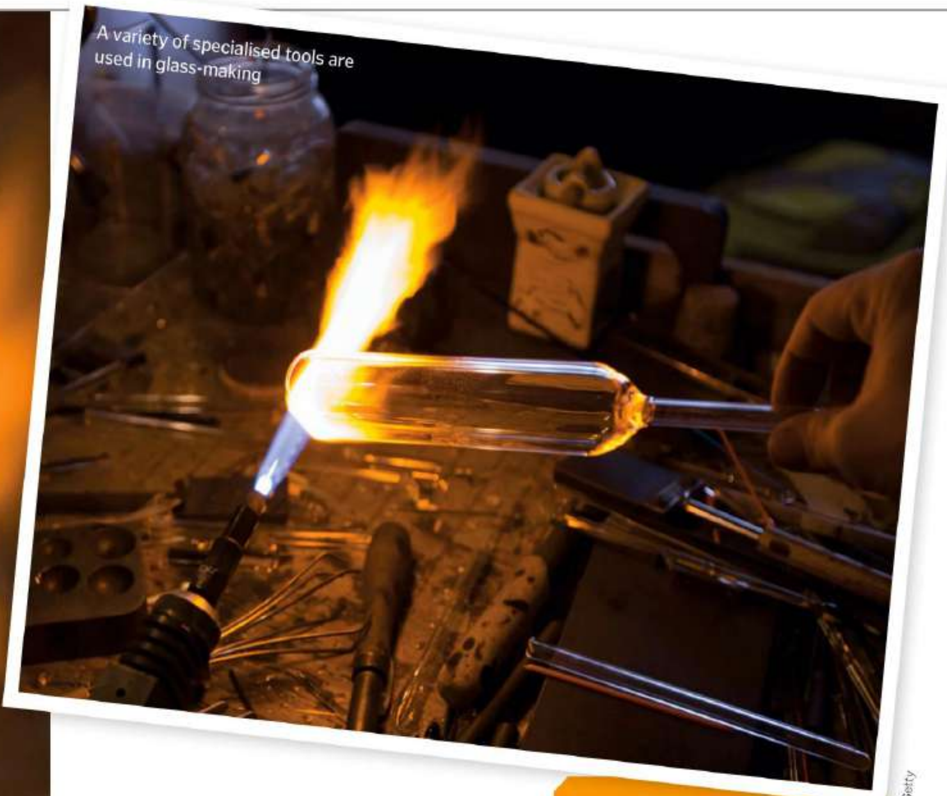
HOW GLASS IS MADE

From its ancient origins to modern-day technology, from bottles to double glazing, what makes this material so versatile?

Words by **Ailsa Harvey**

DID YOU KNOW? *The first known manufactured glass was black volcanic glass, which was used to make weapons*

© Getty



A variety of specialised tools are used in glass-making

© Getty

It's usually encountered as a transparent pane, so it is easy to look past – or right through – glass. But have you ever stopped to think not about the view beyond your window, but of the window itself? This impressively clear, firm material before you is just one of many variations of glass. Glass can be transparent or opaque, coloured or clear, bullet-stoppingly thick or wafer thin. Every day we use it, whether we drink from a bottle made out of it, decorate our homes with it or tap the touchscreens on our mobile phones and tablets. Glass is everywhere.

It can be dangerous. When broken it can form shards that can inflict nasty injuries, while in its ornamental form it's so delicate that an accident can mean a priceless artefact is shattered into thousands of pieces. Either way, glass is usually approached with an element of caution. But how did it come to hold these properties?

Before being manipulated, the components of this handy material are nothing but a pile of sand, rock and minerals. An unlikely combination of

"Glass can be transparent or opaque, coloured or clear"

Safety equipment is necessary when working with molten glass

© Getty

Common glass types

Annealed

This glass undergoes a slow cooling process, which builds its durability. Without using advanced cooling methods, the molten glass is left to cool in a controlled way until it reaches room temperature. This reduces internal stresses that may cause breakages.

Heat strengthened

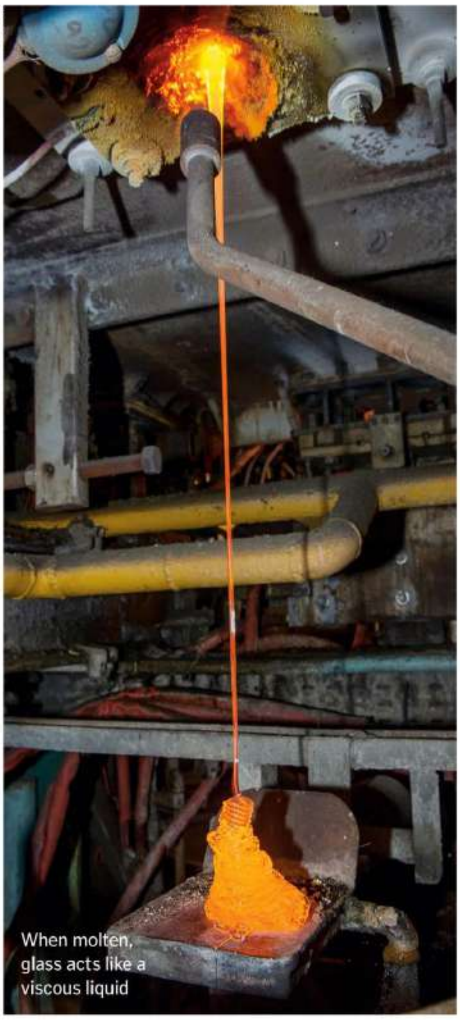
After annealed glass is produced, it can be reheated to temperatures of 700 degrees Celsius and then left to cool again. This doubles the strength of the glass by removing any thermal stress created by pressure changes.

Tempered

Tempering glass involves compressing the outer surfaces. This adds tension to the inner layers and means that if the glass is broken it will break into small, crumbly pieces for safety purposes. This glass becomes four to five times stronger – ideal for car windscreens and shower doors.

Laminated

This consists of more than one layer, bound together with resin. As both panels are unlikely to break at the same time, this resin makes the glass safer by holding layers together when one breaks.



© Getty

When molten, glass acts like a viscous liquid

naturally occurring ingredients, when exposed to extreme heat they produce a fascinating reaction. Molten glass is the product's middle stage, between sand grains and window panes. Baking in a fiery furnace, the red-hot liquid is unrecognisable compared to its final state.

At an atomic level, glass behaves in surprising ways at room temperature. Although it feels solid and is a hard substance to touch, scientists have discovered that glass never reaches a fully solid stage. The reason glass appears to be neither fully liquid nor solid is because it is structured more like a gel.

When glass cools from being a searing, orange inferno, rather than crystallising and its atoms forming a lattice structure, it takes on a more random arrangement instead, creating a tight jam of particles. This makes the glass sturdy enough to appear solid without carrying all the properties of a solid.

As it is, glass is light, transparent and ideal for masses of applications. However, once turned from solid sand and rock to glass, it can't be converted back. This makes glass difficult to recycle. To reuse glass, it can be melted back into its molten form, added to a new batch and reshaped for a different glass product.

Recycling glass is vital to limit the natural resources humans use over time. If everybody put their glass bottles into the recycling bin, the glass already in circulation could be continuously reused without the need to make more. Theoretically this would mean having an eternal supply of glass, without having to use more of Earth's raw materials.

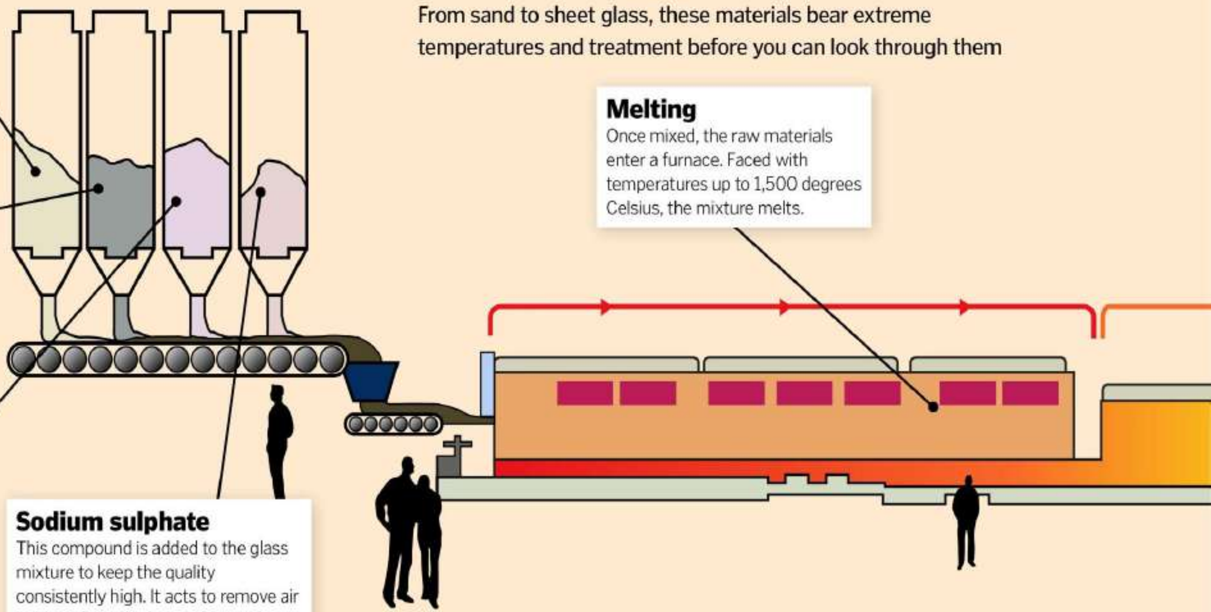
Over 5,000 years have passed since people first explored a new substance that we now know as glass. The 21st century hasn't failed to bring new uses for this flexible and widespread resource. New inventions bring new physical needs, while our expanding knowledge of science only widens the possibilities for a simple and ancient base material. As we evolve to develop technology further, who knows what is possible in the future of glass?

> "Its components are nothing but a pile of sand, rock and minerals"

Raw materials are poured into a glass furnace

Making windows

From sand to sheet glass, these materials bear extreme temperatures and treatment before you can look through them



Silica sand
This is the primary ingredient, and the most common type of sand found in deserts. Consisting almost entirely of silica, the chemical purity of this material helps in making glass transparent.

Soda ash
Also known as sodium carbonate, this essential component reduces the melting temperature of the mixture.

Limestone
Found within rock, limestone adds some desirable physical properties to the finished product, such as durability and chemical resistance.

Sodium sulphate
This compound is added to the glass mixture to keep the quality consistently high. It acts to remove air bubbles from the liquid glass and keeps the substance smooth.

Melting
Once mixed, the raw materials enter a furnace. Faced with temperatures up to 1,500 degrees Celsius, the mixture melts.

History of glass-making

3500 BCE
The earliest glass artefacts that have been discovered are made in Egypt and Mesopotamia.

650 BCE
The first manual is written explaining different glass-making methods. This writing is later discovered in the library of the last Assyrian king, Ashurbanipal.

1 CE
Glassblowing is invented in Babylon. This technique thrives across ancient Rome, allowing the creation of a huge range of glass shapes quickly and cheaply.

100 CE
After glass' rapid growth in popularity, it now holds much less worth, becoming available beyond the wealthy.

1000
With higher demands for glass spreading worldwide, some cities, such as Alexandria in Egypt, become glass-manufacturing centres.

1226
Broad sheet glass begins production in Sussex. Long balloons of glass are blown and then flattened, producing the first window glass in Britain.

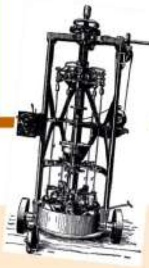
1450
Clear and colourless glass, named 'cristallo' glass, is invented by Angelo Barovier.

1590
Glass for telescopes and microscopes is developed in the Netherlands.

1765
After Caspar Lehmann's method for cutting rock crystal into glass in 1600, crystal glass production begins en masse.

1827
The glass-pressing machine is invented, providing a step forward in mass-produced glassware.

1903
An automatic glassblowing machine is invented by Michael Owens.



1959
Float glass is invented, enabling more control over product thickness.

Metallic tinting

© Getty

In the early days of glass-making, nobody knew how to change or remove the natural colour of glass. Materials were experimented with and their outcomes explored. It was discovered by accident that certain substances gave the glass vibrant colours and others removed the colour.

It is now known that metal oxides can create specific tints. Some of these combinations have become more widely known than others. 'Cobalt blue', for example, is the colour produced by adding small volumes of cobalt to molten glass.

Early glass makers found that red was a particularly difficult colour to make, as it faded quickly. The successful metal was discovered to be small amounts of gold, and today you will notice that red glass can still be more expensive than other hues.

Chrome oxide is used to produce the green glass often found in beer bottles

Glass is laid flat on a cutting bed to cut into panes

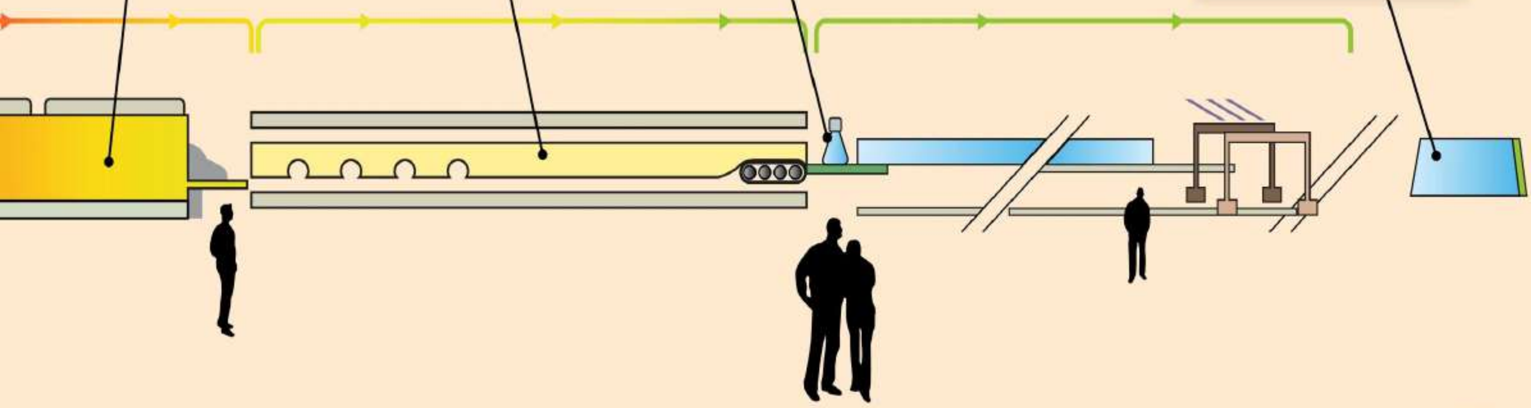
© Alamy

Floating
This section is a float bath. When poured onto a bath of molten tin, the glass floats, keeping it flat at the surface. Turning gears keep the layer moving along the bath and can control the speed and thickness of the glass created.

Annealing
In this cooling phase, the liquid shrinks and begins to crystallise. This is usually a slow process to ease pressures gradually.

Inspecting
In between each stage, workers inspect the production line, ensuring the glass produced is of the highest quality. This inspection can also be automated, with machines scanning for missed bubbles and other inconsistencies.

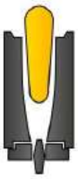
Cutting
A machine at the end of the line cuts the glass to order. The edges of the glass sheets are trimmed for an even sheet and are sold by square metre.



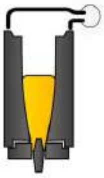
From molten gob to bottle

How do moulding machines produce millions of identical bottles?

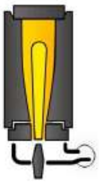
1 Drop the gob Equal measures of the hot molten glass, called gobs, are fired into blank moulds through funnels.



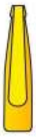
2 Neck formation Sinking to the bottom, the molten glass fills the shape of the bottle neck, but needs to be hollowed.



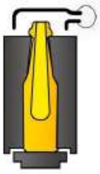
3 First blow Into the neck, which is facing down, air is blown upwards. This pushes the glass away from the centre, forming a gap.



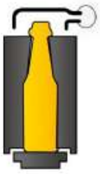
4 Blank shape This is a standard bottle shape after the first stage. It can now be placed into further moulds with differing shapes and designs.



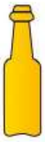
5 New mould A mould with the final bottle shape surrounds the blown blank.



6 Second blow Air enters from the top, pushing the glass further outwards. As it takes shape the glass becomes thinner and cooler.



7 Finished bottle When fully cooled the bottle is clear and solid.



Bottles from identical moulds stand to cool

© Getty

Stained glass explained

One of the most beautiful variations of glass panes, stained-glass panels can be seen decorating old – and often religious – buildings. While coloured glass is technically stained, 'stained glass' usually refers to those which form pictures or patterns. They are believed to have gained their name due to a silver stain which was applied to their outward-facing side. When the glass was heated, this turned golden.

To make a stained-glass window, first an artist is required to draw the chosen image. The pre-made sheet of glass is then laid on top of this drawing, and the lines are followed to cut the pane into appropriately sized pieces. Traditionally the colour was then painted onto the glass. These paints were made with ground-up glass and iron filings. Iron filings were often soaked in urine or wine to aid in capturing the light and colour on the window.

© Getty

Stained-glass windows have been used in Britain since the 7th century

The art of glass blowing

Creating some of the most fragile and intricate ornaments, glassblowing is no subtle affair. When blowing glass there is a space of around 1.2 metres between the blower and the glass. A hollow metal tube uses the power of the lungs to transport bursts of air into the liquid glass at its base. There is incredible skill and technique in mastering this art. In fact, there are so many challenging elements that the process usually requires a team for each item.

First the pipe is dipped into a furnace of molten glass. Due to the extreme heat, the mouthpiece needs to be submerged in cold water until the blower takes position. As air travels into the ball of molten glass at the bottom of the pipe, it expands from the middle, creating a growing bubble. While blowing, the glass is rolled and shaped depending on the desired design. Timing can make or break these glass artworks, but if the glass' temperature drops to the point where it is unworkable, it can always be reheated.

Multiple molten dips can create a layered effect, while other apparatus such as tweezers can be used to manipulate the setting glass for more minute details.

A glassblower's workshop is often called a 'hot shop'

© Getty

Different utensils and techniques create elaborate designs

© Getty

The long blowpipes allow glass blowers to keep their distance from furnaces

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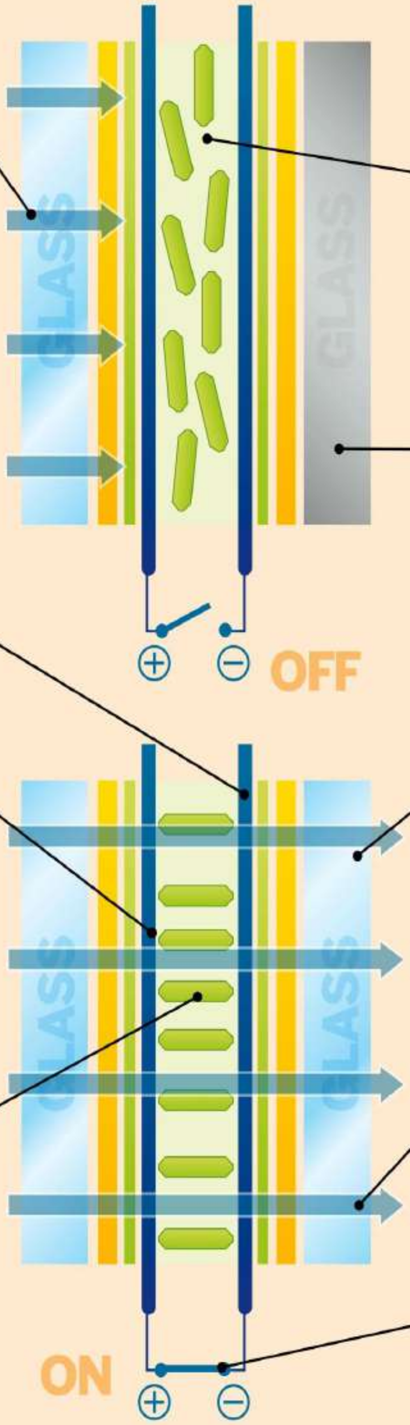
Glass and technology

Inside smart glass

How is glass gaining intelligence?

If there's one quality that is recognised most when it comes to glass windows, it's transparency. This being said, modern glass suppliers have introduced technology that changes this core quality. Have you ever wanted privacy from inside your home, but also wanted to keep natural lighting? Smart glass is able to do just that. At the touch of a switch, Polymer Dispersed Liquid Crystal (PDLC) smart glass uses electricity to alter the chemical properties within the glass and change between transparent and opaque.



Blocked light
When the glass' power is turned off, light cannot travel fully through the window.

Liquid-crystal layer
Between the glass sheets is a layer filled with liquid-crystal molecules. When there is no electric current, these face in different directions, acting as a barrier to block light.

Opaque panel
Light hits the other side of the glass and is reflected back from the glass by its middle layer.

Conductive coating
This layer is essential for carrying electricity around the liquid crystal. It is the low voltage travelling through this coating which charges the surrounding molecules.

Transparent light
Gaps in the centre of the glass allow light to travel fully through the pane, creating a see-through sheet.

Light passage
When the molecules are aligned, light is able to pass through the gaps, creating transparency.

Molecule alignment
When manipulated by the electrical field, liquid-crystal molecules are positioned horizontally. This formation creates more space between them.

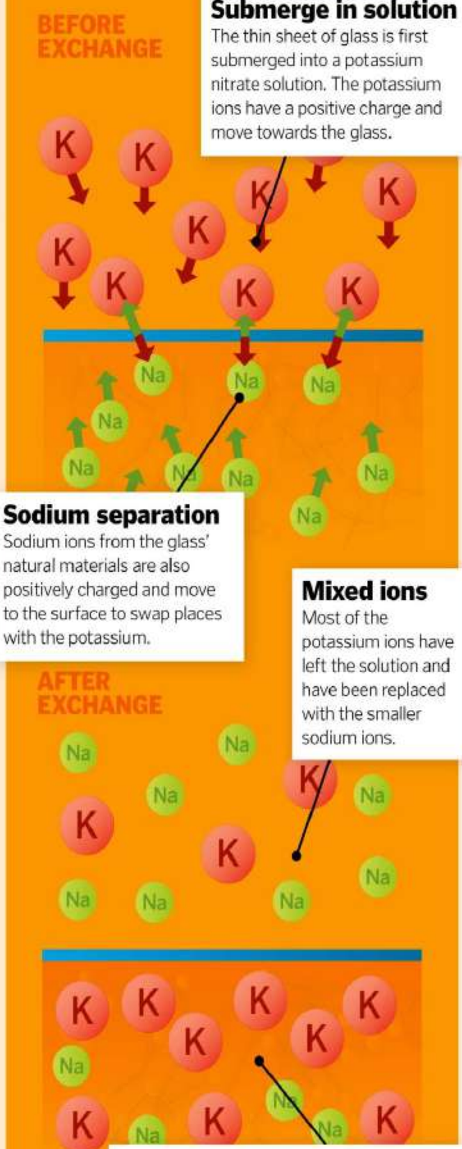
Control switch
This switch determines whether the molecules are charged or not, and therefore whether the window is transparent or not.

Smartphone strength

How thin glass on mobile devices resists shattering

Phones are much more advanced than the chunky devices they used to be, required only for texting or calling. Smartphones store so much data and sentimental photos and are used for multiple jobs, from navigation to research. They help to connect us, and so many of us take them everywhere.

Smart devices have reduced in size, with slimmer models becoming the most desirable. But does slimming down also mean increased fragility? Dropping your new mobile phone may be a frequent fear, but specialised glass helps to give these devices the best protection.



Submerge in solution
The thin sheet of glass is first submerged into a potassium nitrate solution. The potassium ions have a positive charge and move towards the glass.

Sodium separation
Sodium ions from the glass' natural materials are also positively charged and move to the surface to swap places with the potassium.

Mixed ions
Most of the potassium ions have left the solution and have been replaced with the smaller sodium ions.

Stronger in size
The glass now has the potassium ions at its surface. As these are larger, they compress the glass together as it cools. These form a tougher surface, ideal for touchscreens.

© Getty

How anaesthesia works

By interfering with nerve transmission, these special drugs stop pain signals from reaching the brain during operations

Anaesthetics are a form of drug widely used to prevent pain associated with surgery. They fall into two main categories: local and general. Local anaesthetics can be either applied directly to the skin – as a cream, for example – or injected. They are used to numb small areas without affecting consciousness, so the patient will remain awake throughout a procedure.

Local anaesthetics provide a short-term blockade of nerve transmission, preventing sensory neurons from sending pain signals to the brain. Information is transmitted along nerves by the movement of sodium ions down a carefully maintained electrochemical gradient. Local anaesthetics cut off sodium channels, preventing the ions from travelling through the membrane and stopping electrical signals travelling along the nerve. Local anaesthesia isn't specific to pain nerves, so it will also stop information passing from the brain to the muscles, causing temporary paralysis.

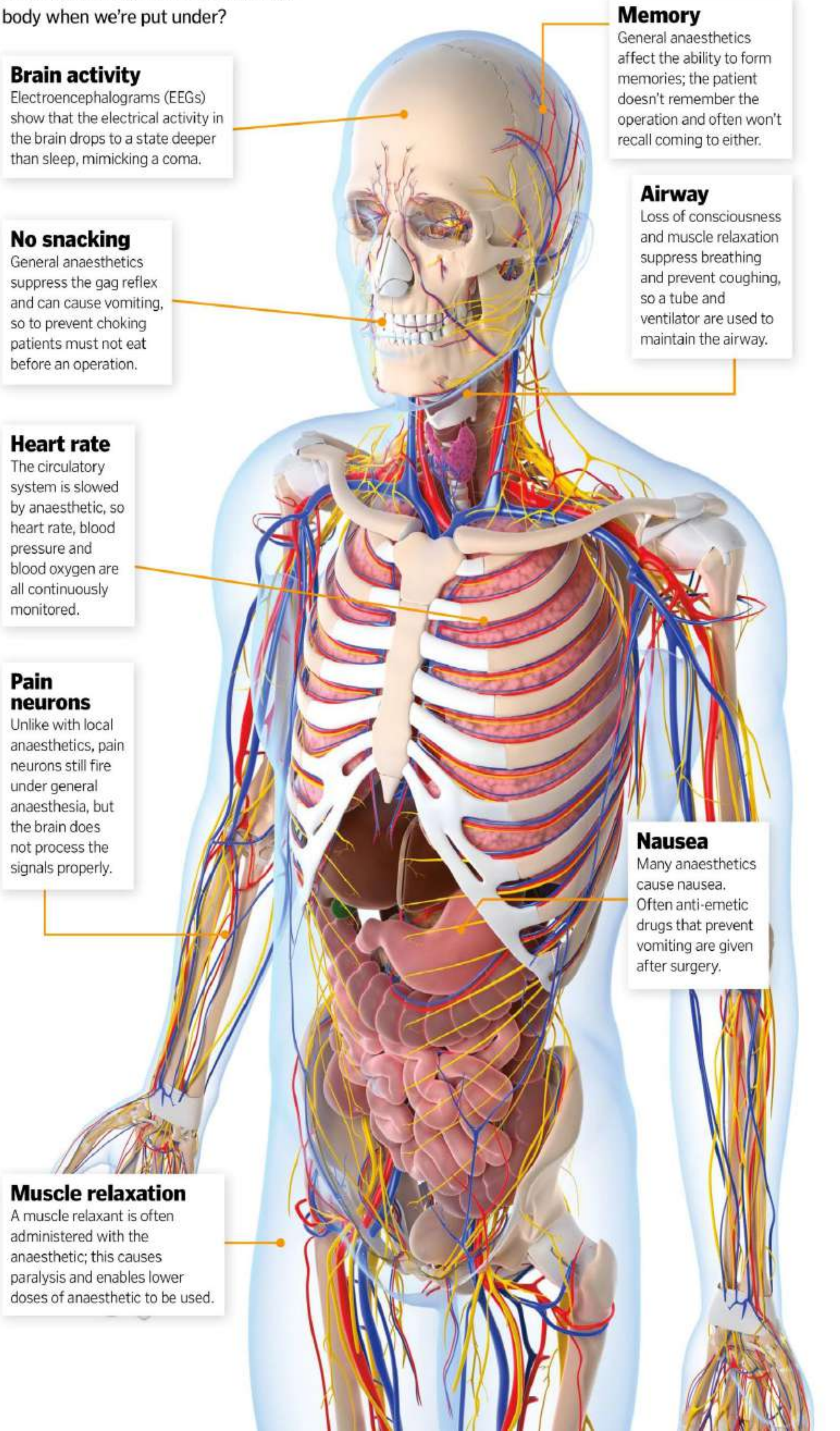
General anaesthetics, meanwhile, are inhaled and injected medications that act on the central nervous system – the brain and spinal cord – to induce a temporary coma, causing unconsciousness, muscle relaxation, pain relief and amnesia. It's not known for sure how general anaesthetics 'shut down' the brain, but there are several proposed mechanisms. Many general anaesthetics dissolve in fats and are thought to interfere with the lipid membrane that surrounds nerve cells in the brain. They also disrupt neurotransmitter receptors, altering transmission of the chemical signals that let nerve cells communicate with one another.

Comfortably numb

If large areas need to be anaesthetised while the patient is still awake, local anaesthetics can be injected around nerve bundles. By preventing transmission through a large nerve, the signals from all the smaller nerves that feed into it can't reach the brain. Injecting anaesthetic around the maxillary nerve will not only generate numbness in the roof of the mouth and the teeth on that side, but will stop transmission from the nose and sinuses too. Local anaesthetics can also be injected into the epidural space in the spinal canal. This prevents transmission through the spinal roots, blocking the transmission of information to the brain.

The body under general anaesthetic

What happens to various parts of the body when we're put under?



Memory
General anaesthetics affect the ability to form memories; the patient doesn't remember the operation and often won't recall coming to either.

Brain activity
Electroencephalograms (EEGs) show that the electrical activity in the brain drops to a state deeper than sleep, mimicking a coma.

Airway
Loss of consciousness and muscle relaxation suppress breathing and prevent coughing, so a tube and ventilator are used to maintain the airway.

No snacking
General anaesthetics suppress the gag reflex and can cause vomiting, so to prevent choking patients must not eat before an operation.

Heart rate
The circulatory system is slowed by anaesthetic, so heart rate, blood pressure and blood oxygen are all continuously monitored.

Pain neurons
Unlike with local anaesthetics, pain neurons still fire under general anaesthesia, but the brain does not process the signals properly.

Nausea
Many anaesthetics cause nausea. Often anti-emetic drugs that prevent vomiting are given after surgery.

Muscle relaxation
A muscle relaxant is often administered with the anaesthetic; this causes paralysis and enables lower doses of anaesthetic to be used.

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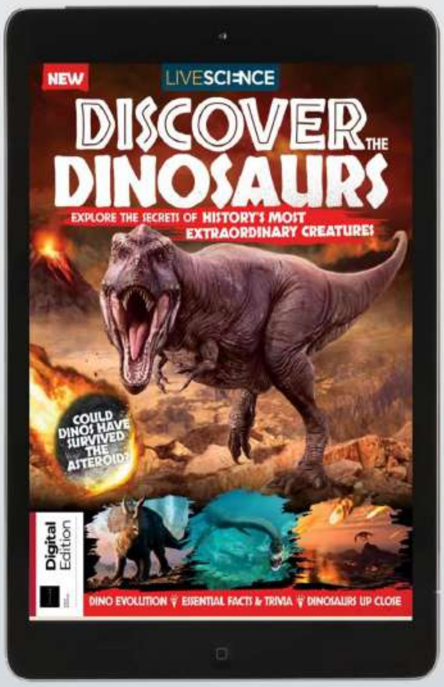
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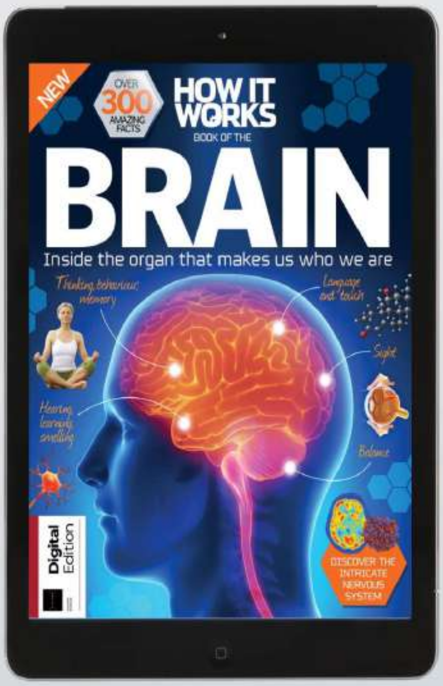
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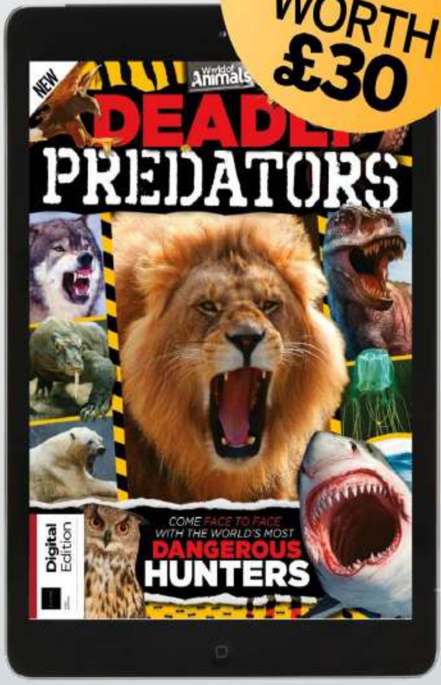
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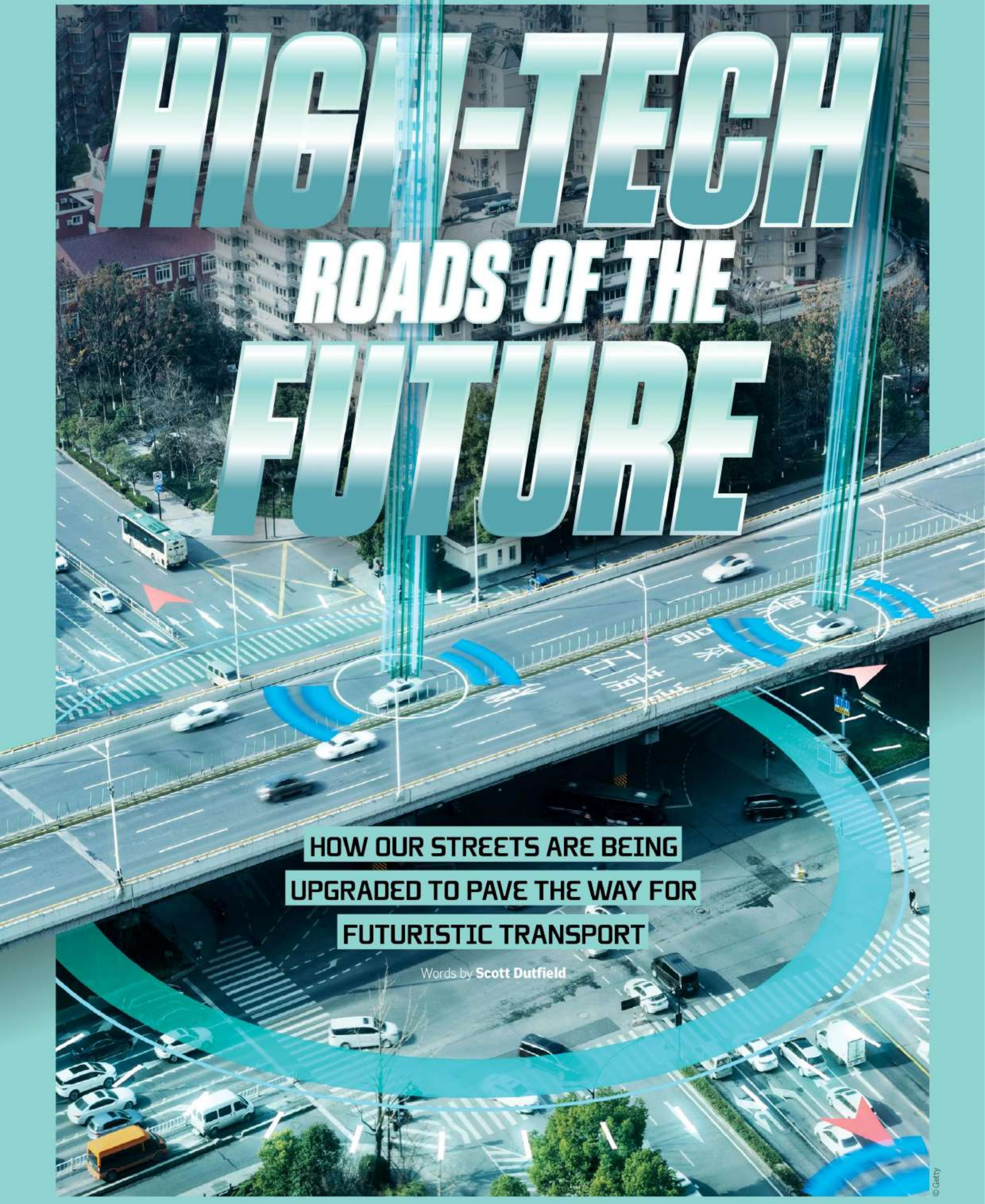


HIGH-TECH ROADS OF THE FUTURE

HOW OUR STREETS ARE BEING UPGRADED TO PAVE THE WAY FOR FUTURISTIC TRANSPORT

Words by **Scott Dutfield**

© Getty

What is a smart road? As our cars become more and more technologically advanced, it seems that the logical progression would be for our roads to follow suit. In the UK stretches of 'smart motorways' have already been installed up and down the country in order to help manage congestion on especially busy highways such as the M1. These roads work using one of two types of sensor. The first is a series of copper loops installed below the surface in regular intervals of a few hundred metres. Connected to a computer for processing, these loops create an electric current whenever metal – such as a car or lorry – passes over them. Collating this information, computer software can calculate the volume of traffic and its speed.

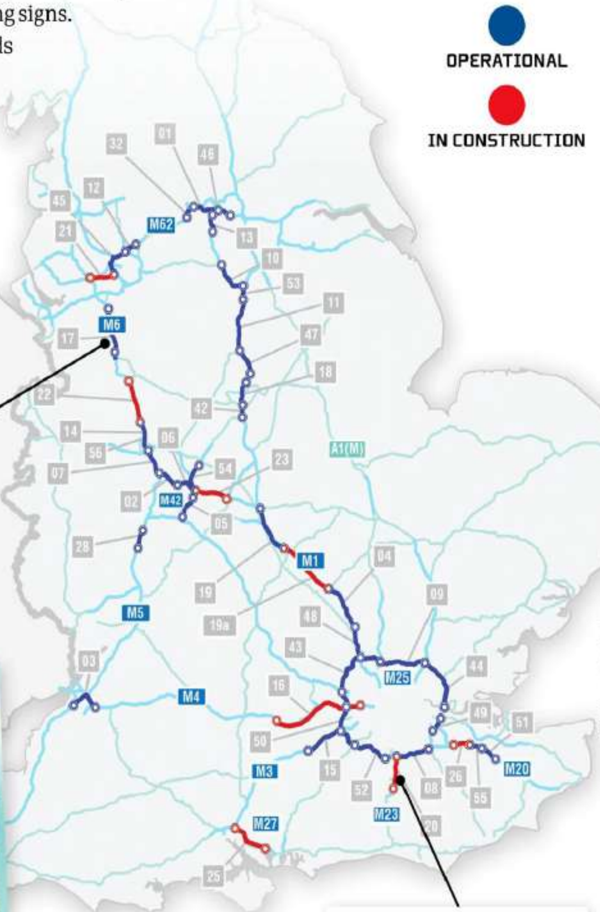
Alternatively, some smart roads are equipped with side-fire sensors, which are placed on posts on either side of the road and cast a beam bilaterally. As cars pass through the beam, information such as speed, quantity and the size of the gap between vehicles can be monitored. Using either method of data collection, a computer can autonomously alter speed limits to ease congestion and open or close lanes along the motorway through overhanging signs.

However, since these smart roads began spreading along the UK's motorways back in 2014 there has been a rise in accidents occurring on the hard shoulder. Sensing an increased level of traffic, these signs might automatically signal a vehicle to drive on the hard shoulder to free up congestion. However, if a car has broken down on the hard shoulder and is awaiting assistance, they are vulnerable to a collision with an unsuspecting driver who has been using the lane as instructed. As a potential solution it's been reported that the UK government plans to stop the hard shoulder being opened as a driving lane.

There are currently around 400 miles of smart roads in use in the UK alone, with many more miles under construction. But is changing the speed limit and filtering lanes the best developers can do when it comes to upgrading our daily commute? It appears not. Across the world there has been a wash of developments in advancing the intelligence of our highways. From roads that glow to vehicle touchpad technology, our highways as well as transport as we know it, could soon be getting an upgrade.

Smart motorway network

There are hundreds of miles of smart motorways in England



A to B
As of October 2019 these are the smart roads currently in operation up and down England's motorways.

Future paths
There are many more smart roads currently under construction in the UK as part of the £15 billion investment by the government from 2015.

© Highways England

© Getty

To ease congestion, smart roads can alter speed limits on both road signs and speed cameras

When good ideas go bad

They're an excellent addition to the roof of your home or lined up in a field to harvest the energy of the Sun, but taking the power production of a solar panel and applying it to a road isn't without its shortcomings. Typically solar panels are manufactured using glass. However, a glass-topped road bearing the weight of passing cars wouldn't last long as a viable surface.

In recent years engineers have been developing ways to take solar panels' energising ability and combine it with the durability of asphalt. However, few have shown long-term viability. In France a valiant attempt at the technology was made in 2016 with the laying of 2,800 photovoltaic panels which cover one kilometre of road in the northwestern town of Tourouvre-au-Perche, Normandy, dubbed the 'Wattway'. Wafer-thin at only a few millimetres thick, each panel is composed of photovoltaic cells submerged in a polymer resin to withstand the trauma of traffic.

Promising the same grip for spinning tyres as a conventionally laid road, these asphalt toppers sparked hope as an alternative energy source that could be implemented without reinventing existing infrastructure. However, that dream was short-lived, as the idea didn't live up to the hype. The Wattway couldn't handle the pressure of ongoing traffic and began to break, not to mention the reported loud noise it produced and the lower-than-ideal power output it provided. If the Wattway is anything to go by, it will be a long time before solar-powered roads grace our highways.

© Getty

The French minister for ecology, sustainable development and energy opens the 'first solar road', in which the French government invested €5 million (£4.5 million)

ROADS OF THE FUTURE

FOLLOW THE MANY AVENUES OF SMART ROAD ADVANCEMENT

Roads that recharge

As the threat of global warming forces us to search for alternative energy sources, why not look to the roads? With the right advancements, cars around the world could be producing energy as they go.

Piezoelectric roads mix traditional asphalt with piezoelectric crystals, using vibrations from passing cars to generate electricity. What makes these crystals unique is their atomic structure. Typically the atoms that build a crystal are symmetrically aligned and harmoniously bound. However, in piezoelectric crystals this atomic foundation isn't as symmetrical. As the crystals are forced under pressure and relaxed again their atoms are pushed closer together, producing an electrical charge. Under the weight of constantly flowing traffic, crystals embedded in the road have the potential to generate a new source of electrical power.

Piezoelectricity is no modern-day revelation, but one first demonstrated back in 1880. However, putting the power production into practice on a large scale, such as entire stretches of roads, has yet to be achieved. Lancaster University is one institution that seeks to change that. Last year the university was awarded £4.5 million to develop the technology and solve issues of energy efficiency and storage in roadside batteries.

Quartz crystals are piezoelectric, generating a small electrical charge when exposed to pressure changes

© Alamy

Sensing the weight of a vehicle, these smart road slabs can track the speed of each wheel

© Intergrated Roadways

Built-in brain

What if the future of smart roads meant that they could know how many people are on the roads and send them updates on weather conditions, collisions or even charge cars as they drive? It's an ambitious feat in engineering, but one American company, Integrated Roadways, is developing a road to do those things.

Using built-in fibre-optic technology and integrated software, these factory-made and site-assembled modular pavements can detect and collect traffic data by recording the pressure applied to the roads. "We're basically making the road into a giant touchpad, but instead of looking for fingers, we're looking for tyres," says CEO and chief technology officer Tim Sylvester.

Thanks to built-in internet connectivity, these smart roads could keep you updated on driving conditions in real-time, but could also be used as a marketing tool to alert drivers of approaching businesses and amenities.

The team at Integrated Roadways has installed 0.5 miles of smart road in Lenexa, Kansas, as part of a development project. Having proved the technology works, Sylvester sees unlimited potential for this technology, with wireless charging for smart cars the next step.

> "WE'RE BASICALLY MAKING THE ROAD INTO A GIANT TOUCHPAD"

A ground glow-up

It's a smart road in terms of technological advancement, and the chemical ingenuity of a road that glows could also transform the way we travel at night. It's a concept that's been floating around since 2014, when Dutch innovator Daan Roosegaarde unveiled his 'Glowing Lines' project, illuminating the world to the possibility of streetlight-free roads.

Roosegaarde used phosphorescent paint to paint lines along 4,500 metres of road southwest of Amsterdam to light up the streets at night. Phosphorescent paint works using phosphor molecules within a liquid paint that become energised by sunlight. During the nighttime the energy is expelled at visible-light wavelengths and glows.

Since the Roosegaarde project there have been several others who have refined the concept of glowing roads. For example, researchers at the Utah Department of Transportation are currently developing a way to make the paint weather-resistant and increase the amount of time it glows.

© Studio Roosegaarde

Studio Roosegaarde created 'Glowing Lines' that are charged by the Sun and can glow for up to eight hours at night

Asphalt antifreeze

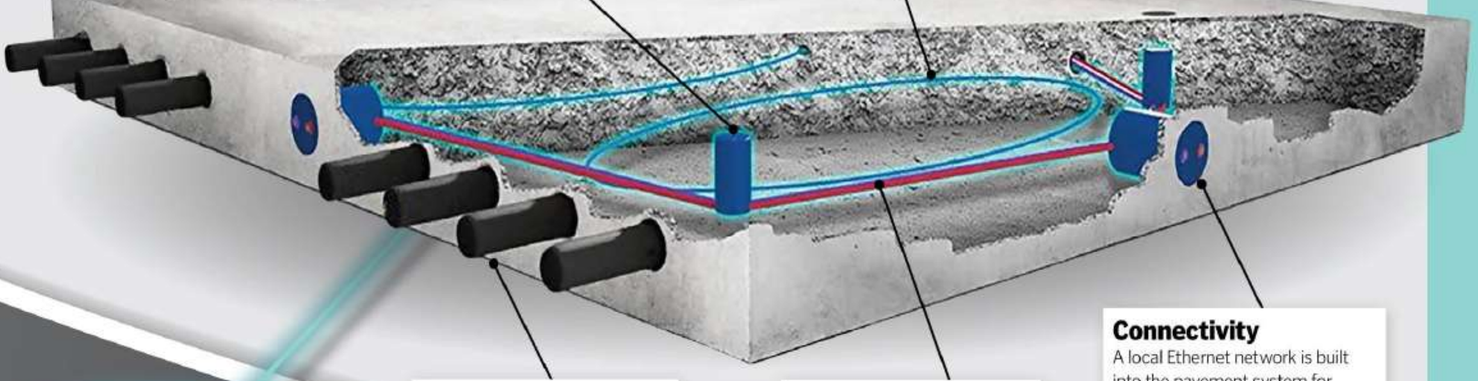
Snow and ice can be dangerous to drive across, but projects such as Snowless – by Israeli-based engineering firm SAN Hitech Ltd. – are carving through the cold to produce roads that melt the ice away. This revolutionary technology involves laying ribbons of a heating alloy in the asphalt of the road surface. Using attached sensors, weather forecasts and temperature drops are monitored. When the presence of snow or ice is detected, the metal ribbons are heated within 15 minutes and can operate at extreme temperatures as low as minus 50 degrees Celsius. The project has been tested successfully in Canadian roads and car parks, with hopes to commercialise the project next year.

© Getty

Underground heating elements have been proven to melt away snow, clearing roads

Inside a smart road

Discover the technology that makes these roads so clever



Fibre-optics
Distributed throughout the pavement, fibre-optic sensing cables measure the way the pavement deforms as cars pass over it. This deformation registers the presence of a car.

Sharing information
Within each slab are four routers that share information with their neighbours that continue along the road.

Modular
Almost like LEGO, each slab of pavement is assembled piece by piece to create a stretch of road. If one piece is damaged or utilities such as pipes underneath need maintenance, a panel can be easily removed and replaced.

Identification
The slab distinguishes between vehicles by identifying the four wheels on a car that are a fixed distance apart, travelling at exactly the same speed.

Connectivity
A local Ethernet network is built into the pavement system for connections to communication modules such as WiFi access, or multi-sensor units for temperature and weather detection.

How wingsuits work

These special suits enable us to glide through the sky at hundreds of kilometres per hour

The human body is built to match our physical needs, but as a species we have the drive to push our physical limits even further. Taking inspiration from the majestic flying squirrel, wingsuits are designed to provide extreme sportspeople with a new body shape: one that allows them to maximise their flying potential.

The ability to jump from a cliff edge or plane and soar through the sky was once deemed to be a possibility only for winged creatures and fantasy superheroes, but these specially designed outfits give those who are brave enough the chance to join native sky-dwellers.

Wingsuits are designed for BASE – building, antenna, span and earth – jumpers and skydivers. Skydivers leap from helicopters and planes, while BASE jumpers take off from fixed objects, such as cliffs or tall buildings. It was Finnish BASE jumper Jari Kuosma who invented today's modern wingsuit as he stood over a clifftop in Italy. What could he do to improve his sport and make the adrenaline-fuelled act of succumbing to gravity even more exhilarating?

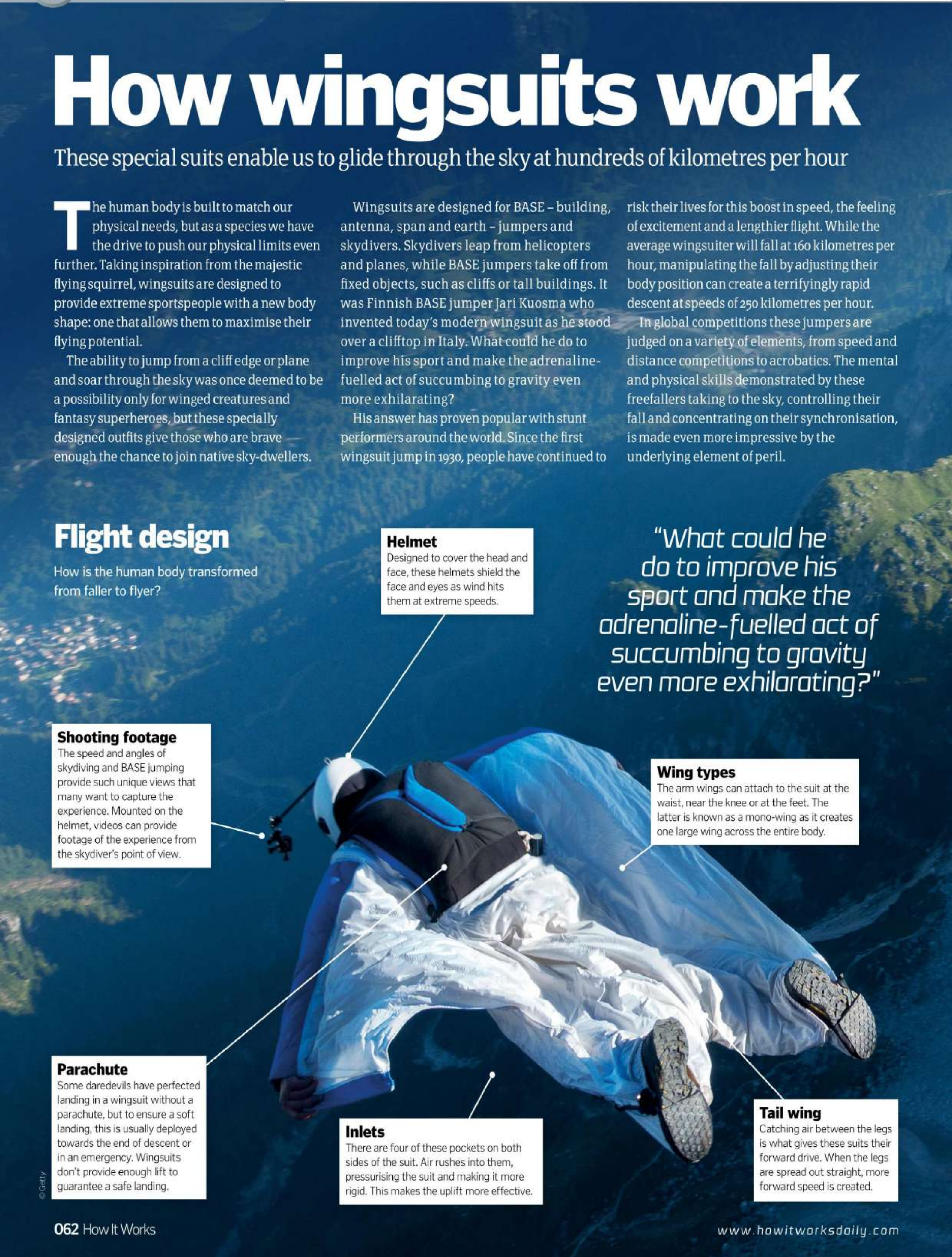
His answer has proven popular with stunt performers around the world. Since the first wingsuit jump in 1930, people have continued to risk their lives for this boost in speed, the feeling of excitement and a lengthier flight. While the average wingsuiter will fall at 160 kilometres per hour, manipulating the fall by adjusting their body position can create a terrifyingly rapid descent at speeds of 250 kilometres per hour.

In global competitions these jumpers are judged on a variety of elements, from speed and distance competitions to acrobatics. The mental and physical skills demonstrated by these freefallers taking to the sky, controlling their fall and concentrating on their synchronisation, is made even more impressive by the underlying element of peril.

Flight design

How is the human body transformed from faller to flyer?

"What could he do to improve his sport and make the adrenaline-fuelled act of succumbing to gravity even more exhilarating?"



Helmet
Designed to cover the head and face, these helmets shield the face and eyes as wind hits them at extreme speeds.

Shooting footage
The speed and angles of skydiving and BASE jumping provide such unique views that many want to capture the experience. Mounted on the helmet, videos can provide footage of the experience from the skydiver's point of view.

Wing types
The arm wings can attach to the suit at the waist, near the knee or at the feet. The latter is known as a mono-wing as it creates one large wing across the entire body.

Parachute
Some daredevils have perfected landing in a wingsuit without a parachute, but to ensure a soft landing, this is usually deployed towards the end of descent or in an emergency. Wingsuits don't provide enough lift to guarantee a safe landing.

Inlets
There are four of these pockets on both sides of the suit. Air rushes into them, pressurising the suit and making it more rigid. This makes the uplift more effective.

Tail wing
Catching air between the legs is what gives these suits their forward drive. When the legs are spread out straight, more forward speed is created.

© Getty

Arm wings
Like an aeroplane wing these are flat on the bottom and have a curved top. As air has to travel faster over the top of the wing, a lifting effect is created. About 80 per cent of lift from a wingsuit comes from the arm wings.

Ribbed material
The surface of the wingsuit is ribbed, creating passages for air to flow through. This prevents drag.

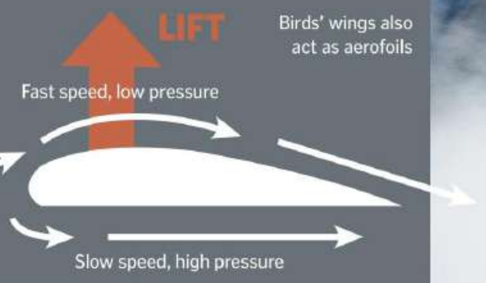
BASE jumping is one of the most dangerous sports in the world

Uplifting physics

Gliding animals make it look simple, but the ability to soar in the air in these wingsuits has been manufactured using carefully applied physics. After observing the wings of flying animals, humans worked out the ideal shape for flight. This shape, called an aerofoil, has been applied to the wings of planes as well as wingsuits. The large, sheet-like design of the suit gives the wearer an increased surface area, which in turn increases the lift. With more material to trap the air rushing past, the fall is slowed down.

Meanwhile it is the air travelling from the person's head along their body that is used in the aerofoil. When air hits the suit, the stream splits, with some of it moving along the curved top and some below the flat bottom. Air travelling over the top moves much quicker, reaching the end of the material first.

As the air above travels down the curve of the wing and off the edge, it continues travelling downwards, changing the flow of the air travelling below it. This effect slows air and deflects it downwards, pushing the person up and backwards and giving a skydiver the sensation of flight as they glide.



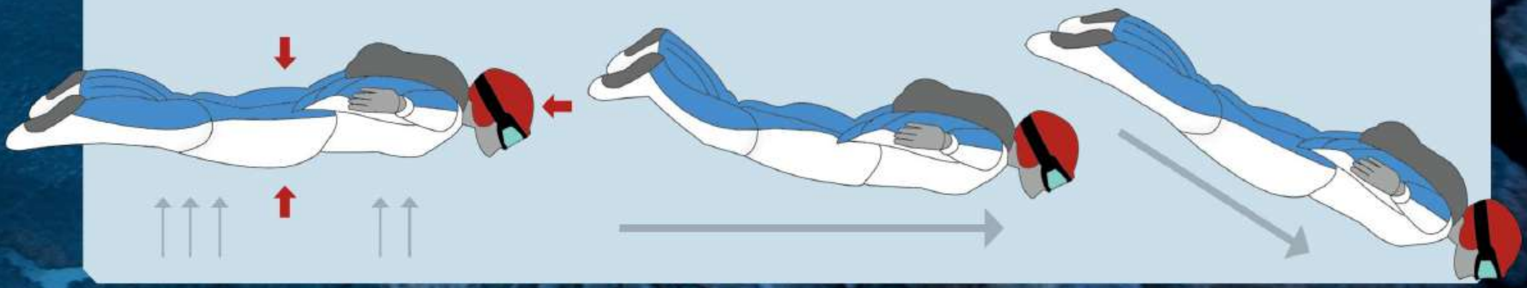
Birds' wings also act as aerofoils

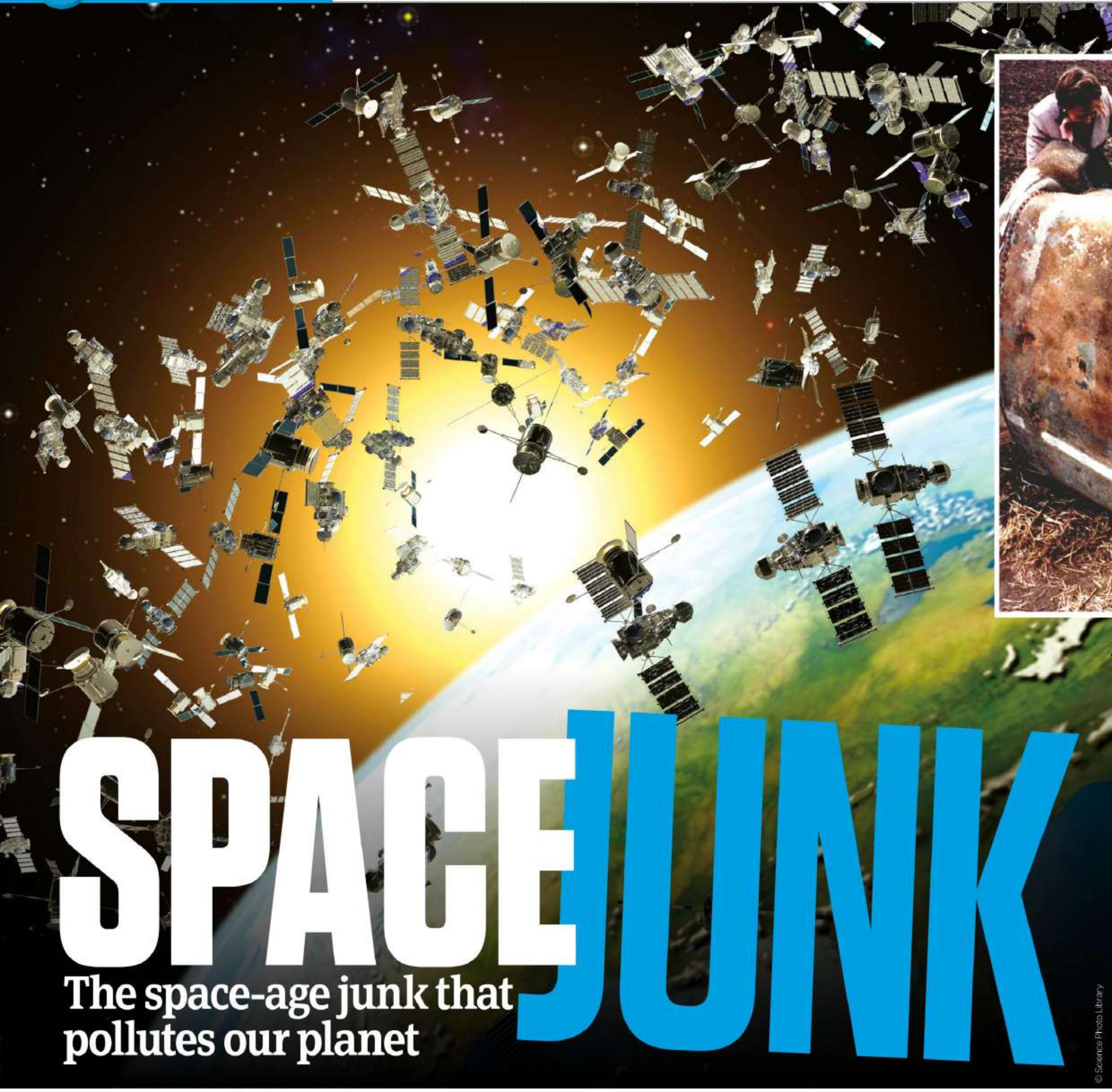
Controlling the fall

Conservative
Lying relatively flat with a slightly curved back is very limiting in forward motion. Keeping the head pointed down helps the jumper to reduce drag. The uplifting air provides an even uplift, but distance travelled is greatly reduced.

Tilt
When the head is below the knees, speed and distance are achieved much more easily. The arms should be kept back to limit drag as much as possible. Each flyer will have their own 'perfect angle'.

Dive
The perfect angle is a fine balancing act. Tilting too far can result in losing altitude too quickly while plummeting to the ground. For most this angle is too steep and will greatly reduce air time.





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SPACE JUNK

The space-age junk that pollutes our planet

Since the launch of Sputnik 1, the first satellite to orbit Earth in 1957, a vast amount of space debris has accumulated in its wake. This consists of anything from flecks of paint to discarded rocket boosters, 'dead' satellites that no longer function and equipment lost by astronauts during spacewalks.

The scale of the problem can be grasped by the fact that there are estimated to be 128 million pieces of space junk between one millimetre and one centimetre, 900,000 pieces between one and ten centimetres and more than 34,000 pieces larger than ten centimetres.

In low-Earth orbit (LEO) this junk travels at an average speed of eight kilometres per second, which is roughly ten-times faster than a bullet. This means that even the smallest objects can damage the subsystems of a satellite. The objects measuring one to ten centimetres are part of a 'lethal population' because they are big enough to do considerable damage to a spacecraft, but are too small to be tracked. Larger debris is tracked and can be avoided; in the case of the International Space Station (ISS), it makes at least one manoeuvre a year to divert it from potentially lethal collisions.

In 2010 there were 13,000 near misses per week, and by 2059 it is predicted that there will be as many as 50,000. The increased need to use rocket fuel to avoid these hazards shortens the life of satellites and increases the cost of launching satellites that need to carry extra fuel.

Around 2,000 large pieces of space junk were created when the first collision between two satellites occurred on 10 February 2009. This was between US communications satellite Iridium 33 and a defunct Russian satellite, Kosmos-2251, 789 kilometres over Northern Siberia. Even worse, about 150,000 pieces of junk were

A propellant tank from a Delta II launch vehicle that landed in Texas in 1997

> "In 2010 there were 13,000 near misses per week, and by 2059 it is predicted that there will be as many as 50,000"

deliberately created when China destroyed an inactive Fengyun-1C weather satellite with a missile as part of an anti-satellite test.

Radar systems are used to track LEO junk, and telescopes are employed to track objects from 2,000 kilometres to 36,000 kilometres in medium-Earth orbit (MEO) and geostationary orbit (GEO) at 36,000 kilometres. Telescopes, however, are only capable of tracking objects that are one metre or more in size. Radio frequency technology can also be used to discover if satellites are operating or not.

Tracking helps warn of possible collisions, but measures that are more drastic are being employed before it is no longer possible to launch manned flights or operate the satellites that provide us with TV signals, weather forecasts, mobile phone networks and global positioning systems.

LOST IN SPACE

What's floating around in orbit?

GLOVE

Lost by Ed White, the first American astronaut to take a spacewalk, on 3 June 1965 during the Gemini 4 mission

Ed White's first spacewalk

CAMERAS

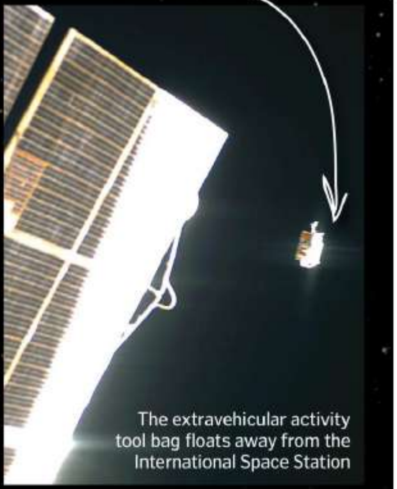
Lost during the Gemini 10 mission and a Space Shuttle Discovery mission in December 2006

200 RUBBISH BAGS

Ejected by cosmonauts on the Mir space station from 1986 to 2001

TOOL BAG

The bag contains grease guns lost by Heidemarie Stefanyshyn-Piper during a spacewalk in 2008. It re-entered the atmosphere in August 2009



The extravehicular activity tool bag floats away from the International Space Station

128KG OF NUCLEAR REACTOR COOLANT

Leaked from inactive Soviet Radar Ocean Reconnaissance Satellites

480 MILLION COPPER NEEDLES

Launched in 1963 as part of Project West Ford to create an artificial ionosphere, the needles encircled Earth at 3,700 kilometres. Some are still in orbit

MYSTERIOUS METALLIC SPHERICAL OBJECTS

Started a UFO scare when they crashed in Western Australia in 1965, but were identified as coming from the Gemini spacecraft

300,000 FRAGMENTS

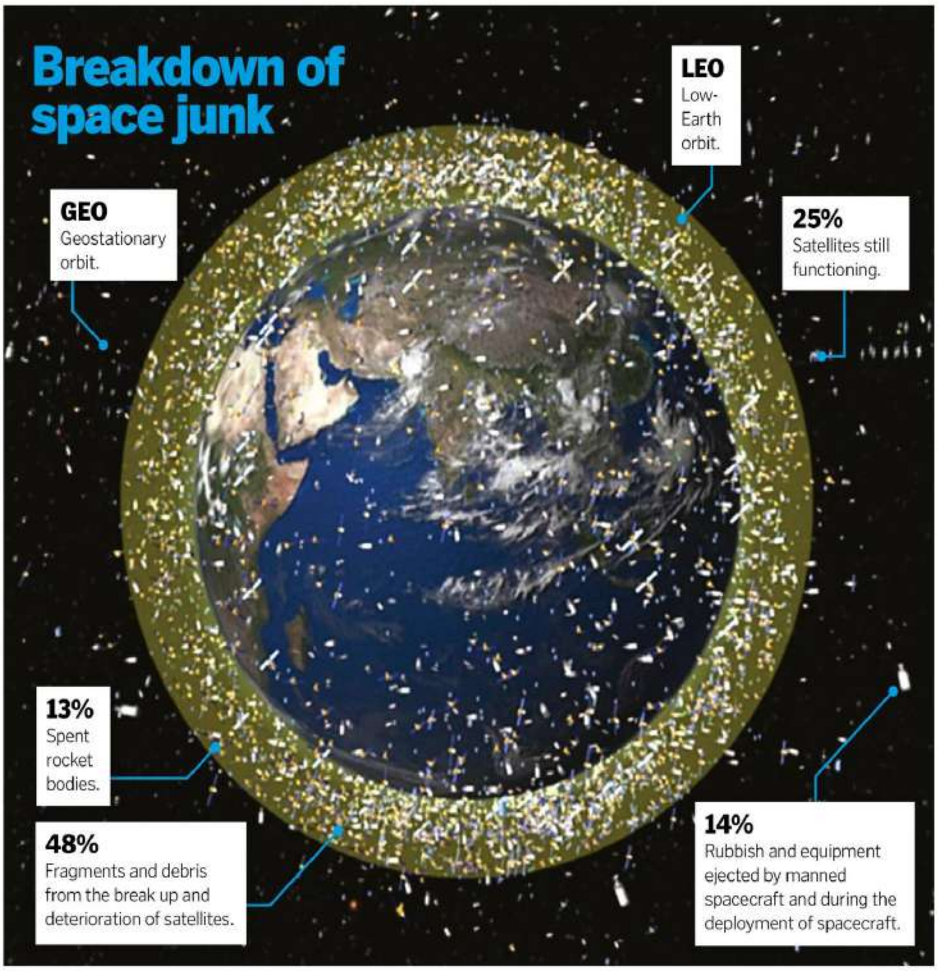
Produced when the upper stage of a Pegasus rocket exploded in 1996

GENE RODDENBERRY

His ashes were released in a small capsule by a Pegasus XL rocket in 1997

Gene Roddenberry and the cast of *Star Trek* attending the rollout of Space Shuttle Enterprise in 1976

4 x images / stary background © NASA



Breakdown of space junk

LEO Low-Earth orbit.

GEO Geostationary orbit.

25% Satellites still functioning.

13% Spent rocket bodies.

48% Fragments and debris from the break up and deterioration of satellites.

14% Rubbish and equipment ejected by manned spacecraft and during the deployment of spacecraft.

© NASA

Debris in low-Earth orbit

A snapshot of the junk orbiting Earth

Objects in low-Earth orbit (LEO) are between 160 and 2,000 kilometres above Earth. Military satellites, Earth-monitoring satellites and communications satellites all operate at these orbital altitudes.

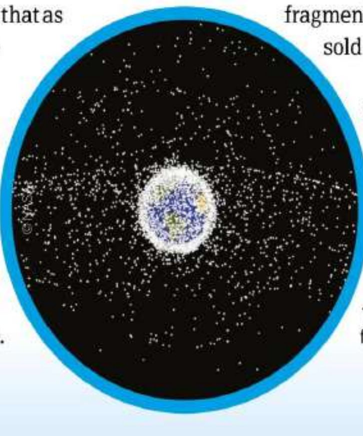
LEO satellites pose a problem because they orbit Earth at least 15 times a day along different orbital planes to provide global coverage. This gives them a higher chance of hitting other satellites in contrast to those that keep to the elliptical plane of the Sun. In addition they have shorter battery lives and are more vulnerable to the gravitational pull of Earth than satellites orbiting higher up.

Kessler syndrome proposes that as collisions multiply they create even greater numbers of fragments that will start an unstoppable chain reaction of collisions. In this process the debris will increase more than the amount of debris burnt up by orbital decay, and will make the use of low-Earth orbits impossible.

Most objects that go beneath LEO fall back to Earth and harmlessly burn up in the atmosphere. Larger space junk is more of a problem. This was emphasised by the accidental crash of Kosmos 954 in January 1978. The Soviet reconnaissance satellite carried an onboard nuclear reactor, which instead of reaching a safe orbit fell over northwest Canada. A huge recovery operation found 12 large pieces, ten of which were radioactive.

In 2001 the Russian Mir space station was deliberately made to crash into the Pacific Ocean. The re-entry of the 130,000-kilogram station created a spectacular display, and metal fragments from it were recovered and sold on eBay.

So far such crashes have been in oceans or remote parts of the world, but there is certainly a risk of a rogue piece of space junk causing serious damage to a highly populated area.

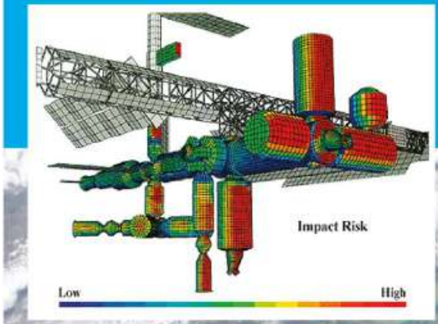


The majority of the debris floating in space lurks in LEO

How the ISS dodges debris

Orbiting 400 kilometres above us in low-Earth orbit, the ISS is particularly vulnerable to damage from space debris. Manned modules and other vulnerable areas have been fitted with protective aluminium shields – both during and since construction. The ISS also carries out debris avoidance manoeuvres to dodge space junk or micrometeorites. After being warned of such dangers, the ISS is sent a few kilometres higher or lower using a short engine thrust from a docked Automated Transfer Vehicle (ATV) or Progress spacecraft. The ATV is fitted with an automatic system that will abort the docking procedure if it detects any danger from debris.

If any debris comes within 0.75 kilometres above or below the space station, or within 25 kilometres around it that cannot be avoided, the ISS is put into unmanned mode and the astronauts have to seek protection in a spacecraft docked with the station. In 2008 and 2009 astronauts had to seek refuge in a Soyuz craft due to such warnings.



One line of defence for the manned modules is aluminium shielding

Soyuz crew transfer vehicles
In debris emergencies the Soyuz craft can transfer the crew back to Earth.

ATV propulsion
Docked at Zvezda is an ATV whose thrusters can move the ISS to avoid collisions.

© NASA

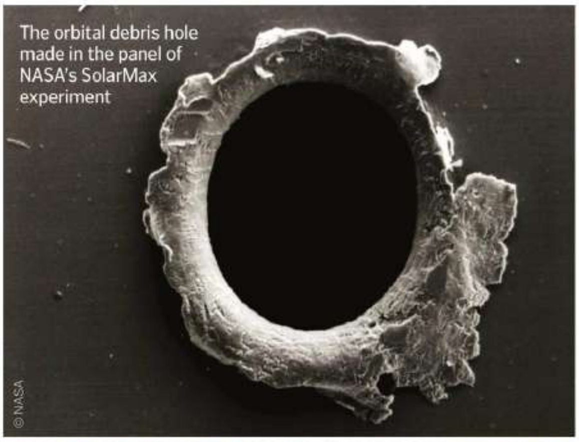
DID YOU KNOW? *More than 178,000 kilograms of hardware has been junked on the Moon*

Damages

The relative velocity of a space vehicle and a piece of junk can be ten kilometres per second, making a collision very damaging. In the case of manned flight it is even more threatening. The US Space Shuttles often encountered debris, causing NASA to regularly replace cabin crew windows and thermal tiles damaged by flecks of paint or micrometeorites.

A more threatening incident happened to Columbia in 1995, when an object penetrated the protective layers of its payload bay door. Another collision between an object and Atlantis' payload door in September 2006 created a 12-millimetre-deep hole. To reduce such impacts the shuttles flew tail-first in orbit. When docked to the ISS they were positioned so that the station took the worst impacts.

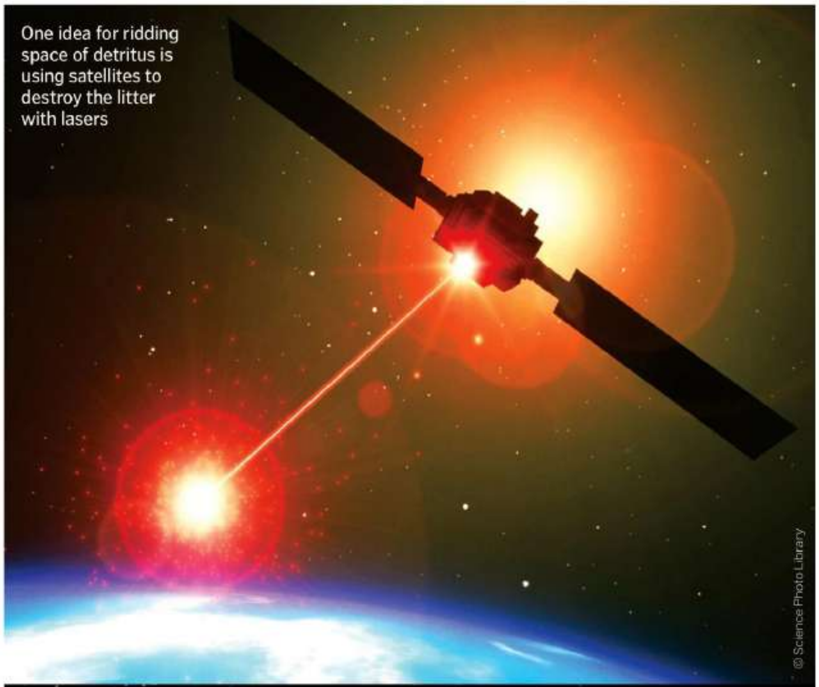
Whipple shields that absorb debris impacts before they can do any significant damage can protect manned and unmanned spacecraft alike. Unfortunately such shields cannot protect vital solar panels or stop the impact of larger debris. To tackle large debris spacecraft have to manoeuvre out of the way to avoid a collision.


The orbital debris hole made in the panel of NASA's SolarMax experiment

© NASA

Shielding
Vulnerable areas of the space station are protected by shields.

Zvezda module
Zvezda is fitted with six service module debris protection shields.


One idea for ridding space of detritus is using satellites to destroy the litter with lasers

© Science Photo Library

Dealing with the space junk

The European Space Agency is currently building a radar system to catalogue and track hazardous objects in Earth orbit. At the moment the US Space Surveillance Network (SSN) tracks 26,000 objects, and its Space Fence radar system, becoming operational in March 2020, will track as many as 200,000 objects.

To mitigate the problem of space junk the Inter-Agency Space Debris Coordination Committee (IADC) was formed in 1993 to produce a set of guidelines. It advocates several preventative measures, including reducing the amount of hardware ejected or rendered inoperative by a space mission. Since accidental orbital explosions have accounted for at least 500 incidents, it is recommended that explosive gases or fuels be vented to stop this happening. The deliberate explosion of satellites should be stopped, and where possible satellites should be steered clear of debris. As LEO satellites are the biggest culprit, they should be designed to only have an orbital life of 25 years and carry drag devices or a propulsion system to send them into re-entry if their orbit is not low enough for them to naturally re-enter. Higher satellites should be designed to enter a 'graveyard' orbit at the end of their operating life.

Several ideas have been proposed to dispose of existing space junk. They range from shooting debris down using lasers, scooping it up with Aerogel material or netting it with 'trawler' satellites. For the smallest debris, large panels of porous foam could slow down junk that passes through it, making it re-enter the atmosphere. For larger debris, it could be collected by the robotic arm of an unmanned spacecraft.

The Hypervelocity Ballistic Range at NASA's Ames Research Center simulates orbital debris hitting a spacecraft by launching a projectile at a solid surface. This image shows the resulting energy flash

Hypervelocity picture and stary background © NASA

NASA's Viking program

The Viking program of the mid-1970s was a triumph in space exploration

NASA's Viking program was the first mission to return numerous images and scientific data from Mars. It comprised two identical spacecraft – Viking 1 and Viking 2 – each with an orbiter and a lander.

Both launched using a Titan IIIE/Centaur launch system. Viking 1 launched on 20 August 1975, reaching Mars after a ten-month journey. The orbiter took images and transmitted them to NASA, who used them to choose a site for the lander. On 20 July 1976 the lander separated from the orbiter and landed in an area called Chryse Planitia. For more than six years the lander took images and collected data from the surface. The orbiter's fuel ran out on 7 August 1980, while the lander shut down on 13 November 1982 when a mistake during a software update caused its antenna to go down.

Viking 2 launched on 9 September 1975, reaching Mars orbit on 7 August 1976. The lander touched down in the Utopia Planitia on 3 September. Viking 2's mission did not last as long as Viking 1; the orbiter shut down after a fuel leak about two years after arrival, while the lander had a battery failure after three-and-a-half years. Together Viking 1 and 2 provided more than 50,000 photographs of Mars.

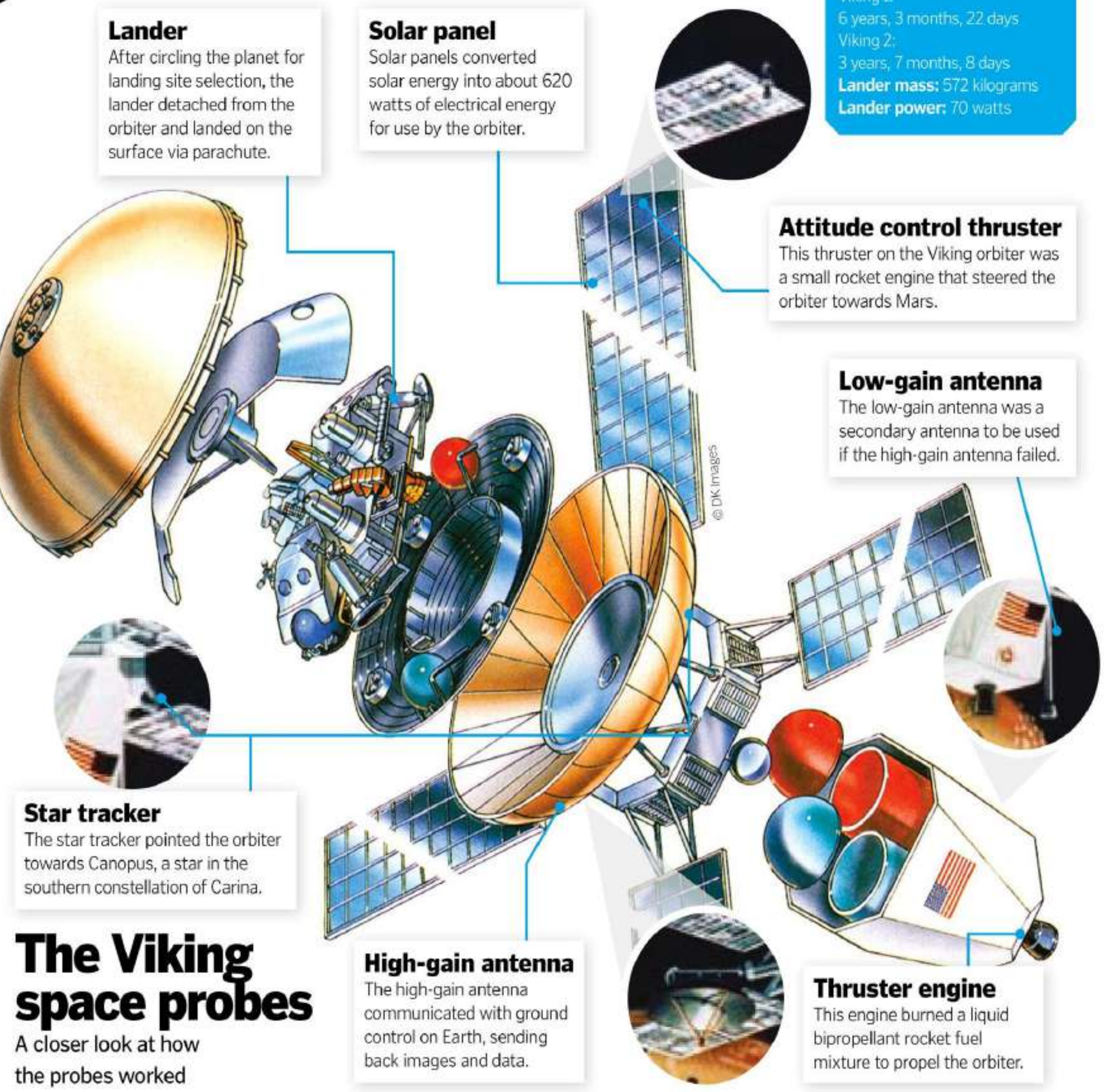
The statistics

Viking landers

Launch date:
Viking 1: 20 August 1975
Viking 2: 9 September 1975
Launch site:
Cape Canaveral
Launch vehicle:
Titan IIIE/Centaur
Mission length:
Viking 1:
6 years, 3 months, 22 days
Viking 2:
3 years, 7 months, 8 days
Lander mass: 572 kilograms
Lander power: 70 watts

The Viking space probes

A closer look at how the probes worked



Lander
After circling the planet for landing site selection, the lander detached from the orbiter and landed on the surface via parachute.

Solar panel
Solar panels converted solar energy into about 620 watts of electrical energy for use by the orbiter.

Attitude control thruster
This thruster on the Viking orbiter was a small rocket engine that steered the orbiter towards Mars.

Low-gain antenna
The low-gain antenna was a secondary antenna to be used if the high-gain antenna failed.

Star tracker
The star tracker pointed the orbiter towards Canopus, a star in the southern constellation of Carina.

High-gain antenna
The high-gain antenna communicated with ground control on Earth, sending back images and data.

Thruster engine
This engine burned a liquid bipropellant rocket fuel mixture to propel the orbiter.

© DK Images

The Viking landers' discoveries

The Viking program was the first truly successful mission to Mars, providing NASA with the first real data concerning the existence of water on the Red Planet. Photographs showed large areas of erosion, channels and grooves in rocks, as well as river valleys. These were likely caused by massive amounts of water. Each Viking lander also carried four different types of experiments to test for signs of life on Mars, which included testing for carbon and gas concentrations in the soil. The results of three of the tests proved negative, while one was ultimately inconclusive.

This panoramic image was taken by Viking 1. It reveals large rocks and sand dunes on the surface of Mars, as well as a layer of clouds below the horizon

All unmarked images © NASA

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BRAIN DUMP

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Proxima Centauri is a red dwarf star and is smaller than our Sun

How long would it take to get to the next planetary system?

Yob Fashipe

■ A long time! Alpha Centauri is the closest star system to us, and is made up of three stars: Alpha Centauri A and B and Proxima Centauri. The closest of these three to the Sun is Proxima Centauri, which is confirmed to host at least one exoplanet. Even though it's the Sun's closest neighbour, it is still 4.22 light years away – that's about 39.9 trillion kilometres. With current technology this great distance would take generations to traverse. However, if humans are able to develop light-speed travel in the future, we could reach Proxima Centauri in just over four years. **NR**

DID YOU KNOW?

NASA spacecraft Voyager 1 and 2 have both reached interstellar space

© Getty

Why does the speed of sound differ through different mediums?

Laila Jones

Because water, for example, is much more dense than air, allowing the wave to travel quicker through it. The density of the medium through which sound is travelling will affect the speed of the sound wave. Sound typically travels faster through a solid than a liquid, and slower through a gas. For example, through room-temperature air sound travels at around 343 metres per second. Through water, however, sound travels much faster at about 1,480 metres per second. **NR**

Sound travels in waves, vibrating through different mediums

© Getty

© Getty

Why do we get pins and needles?

Emily Mei

Pins and needles, also known as temporary paresthesia, occurs when pressure is applied to a limb, restricting blood vessels' ability to supply oxygenated blood to nerves and temporarily turning them off. Upon relaxing pressure the nerve regains its blood supply and switches back on, creating a tingling sensation. **SD**

DID YOU KNOW?

The first antibiotic, penicillin, was discovered by Alexander Fleming in 1928

African bush elephants are the largest living land animals

© Pixabay

Why aren't today's animals as big as the dinosaurs were?

Eiliah Jane

Bigger creatures require more food and spend their days constantly eating. Large animal species today can usually be found grazing on grasslands. This strategy is the most effective for large herbivores, but when dinosaurs roamed Earth, grass had not yet evolved. It's believed that most dinosaurs were plant eaters, and becoming taller was essential to reach higher trees. Any animal with a large neck needs a large tail for balance. Additionally, taller animals require thicker bones for more muscles to attach to, as well as wider legs to carry the weight. Ultimately these factors created much bigger animals in order to meet the needs that many animals today simply don't have. **AH**

How would electricity be different if it was positively charged?

Theo Schmidt

Although electricity is created by the movement of negative electrons, electric current is conventionally defined as being a positive flow. This is due to the creation of positive charge in the opposite direction as electrons move away.

To switch these charges, the flowing particles – known as charge carriers – would need to be positive. The positive part of atoms are the protons, and while a positive flow of protons does exist in nature, this electrical current is not classed as electricity. **AH**

© Pixabay

BRAIN DUMP

©NASA

What's in interstellar space?

Nevaeh Reed

Practically nothing. Known as the interstellar medium, the space between stars is not completely empty. It's mostly made up of hydrogen gas, but also contains traces of other gases and dust. The molecules of gas and dust in interstellar space are widely spread out, but some areas are more concentrated than others. **NR**

Should I drain my mobile phone battery fully before recharging it?

Monica Rowe

Only with old mobile phones, whose batteries modified their range according to the way they were used. To slow the rate at which the battery in a new mobile phone declines, it's best to maintain your battery between 90 and 20 per cent charge. The more charge cycles you put the battery through, the less charge it will hold. Generally speaking, the less often you drain and then recharge your phone, the longer its battery will last. **BB**

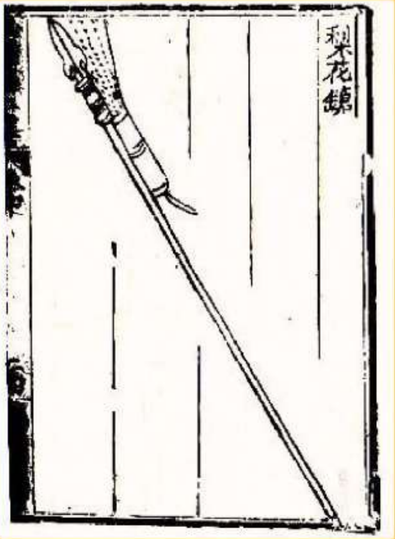
O2-UK
09:00
Tuesday 21 December
100%
slide to unlock
mophie

© Getty

Why have humans evolved to scratch itches?

Stephen Conn

Feeling an itch is one of the ways humans and mammals have evolved to alert us to trauma occurring on the skin, such as a bite or sting. Scratching that itch would have once been a good way of removing whatever is penetrating the skin, long before tweezers were invented. Scratching also sends a signal to the brain that the bite or sting is being addressed and the itching sensation is turned off. **SD**



©wiki

When did guns replace bows and arrows in battle?

Jiao Wu

Fire lances, first used by the Chinese in the tenth century, were the earliest recognisable form of gun: spears were tipped with metal tubes containing gunpowder, that shot flames and shrapnel at their targets when ignited. **BB**

DID YOU KNOW?

The largest living animal, a blue whale, can grow to be over 30 metres long

© Pexels/ Trove Liu

Why do planes have round windows?

Jeff Jacobs

Curved shapes make the best plane windows because they distribute stress better. Windows used to be square-shaped in some of the first aeroplanes, but the pointed corners created weak spots. Rounded windows were found to be stronger, which is ideal for the exposure to extreme pressures that comes with flying at high altitudes. **AH**

Why are bacteria easier to kill than viruses?

Karl Sheldon

A virus is a pathogen that reproduces using human cells, whereas a bacterium is a single-celled organism reproducing by itself. This biological difference is the reason that one is easier to treat. Antiviral medication is made to kill the virus without harming hijacked human cells, whereas an antibiotic can be designed to eliminate bacteria without this risk. We can more readily kill bacteria by preventing it from forming its cell wall, made from a polymer called peptidoglycan. This polymer isn't found in human cells, therefore the risk of human cell damage is reduced. **SD**

Antibiotics don't kill all bacteria: an estimated 61,000 antibiotic-resistant infections occurred in the UK in 2018

© Getty

DID YOU KNOW?

A whip was the first human-made object to break the sound barrier, 2,000 years ago

If a jet made no noise, would it still do a supersonic 'bang'?

Arthur Alaphilippe

No, it wouldn't. A sonic boom happens when a noisy object, like a jet plane, travels faster than the sound it produces. Sound cannot travel through space, as it's almost a total vacuum, so spacecraft that travel many times the speed of sound cannot create a sonic boom. Aerospace company Lockheed Martin has a jet in development that produces a gentle sonic 'heartbeat' when it breaks the speed of sound, so in the future there may be noisy supersonic jets in our skies that are able to pass through the sound barrier without the ear-splitting, signature sonic 'boom'. **BB**

The Lockheed Martin X-59 QueSST is a supersonic passenger jet that has a quiet sonic boom. It will have its debut flight in 2021

© Lockheed Martin

Want answers?

Send your questions to...

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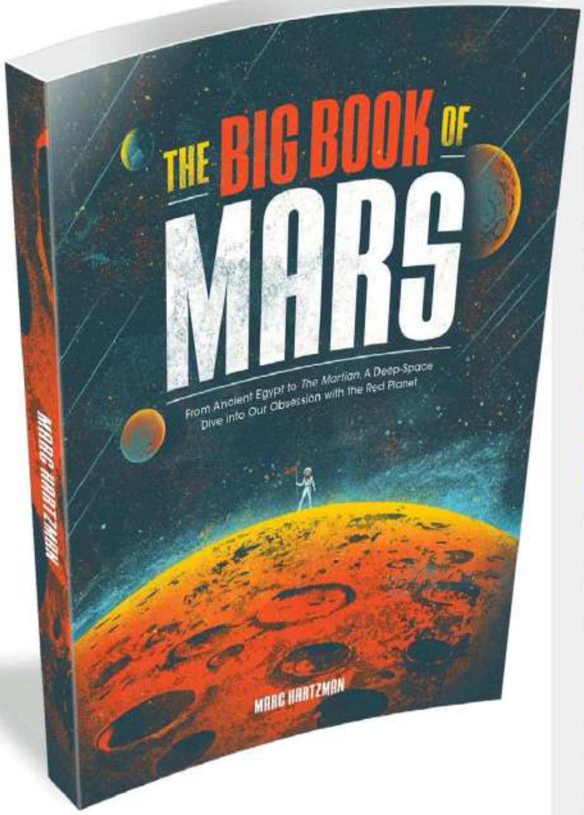
BOOK REVIEWS

The latest releases for curious minds

The Big Book of Mars

How obsessed are we with the Red Planet?

- Author: **Marc Hartzman**
- Publisher: **Quirk Books**
- Price: **£19.99 / $24.99**
- Release: **Out now**


THE BIG BOOK OF MARS
From Ancient Egypt to The Martian, A Deep-Space Dive into Our Obsession with the Red Planet
MARC HARTZMAN

Marc Hartzman's latest literary work could be described as a kind of alternative history of Mars observation. It's not a stuffy chronology of scientific discoveries through the eyes of Hershel, Galileo and astronomers from antiquity – although there is a bit of that just for context.

Instead within these pages Hartzman likes to focus on the fun stories from Mars astronomy, many of which are much more likely to be heard in a university sociology lecture than a secondary school physics class, like the 1912 theory that Mars is a vegetable with an eyeball that watches over it, for example, published in the *Salt Lake Tribune*. Or the 19th-century proposal to communicate with Martians by burning messages onto the surface of the planet with a giant magnifying glass. Crazy science today, but not so much for its time.

There's a very apt prelude to this apparent nonsense where Hartzman explains how he was researching the efforts of Nikola Tesla, the electrical engineering pioneer of Tesla coil fame, to communicate with our planetary neighbours, when he discovered Hugh Mansfield Robinson. This chap snatched the author's attention away from Tesla with his utterly bonkers belief that he was able to communicate, telepathically, with the Martian race via a two-metre-tall Martian woman called Oomaruru. Robinson's theory would be relegated to the crackpot fringes today, but in the 1920s, when it was still believed that the network of lines criss-crossing the Red Planet were canals dug by Martians, it held weight with the public imagination, if not the scientific community.

Hartzman likes to focus on the fun stories from Mars astronomy

The author links through to the modern era with the formation of NASA's Jet Propulsion Laboratory (JPL), when Jack Parsons, inspired by the wildly fantastic science-fiction stories of 19th-century novelist Jules Vernes, decided to build rockets with a few fellow students. Between his increasing occupation with the occult and becoming friends with Scientology founder L. Ron Hubbard, he helped launch the US space program.

Hartzman has clearly enjoyed researching and writing *The Big Book of Mars* as much as we've had reading it. As an extracurricular read, you'll learn a lot of very surprising things about our centuries-old relationship with the Red Planet and have a lot of fun in the process.

★★★★★

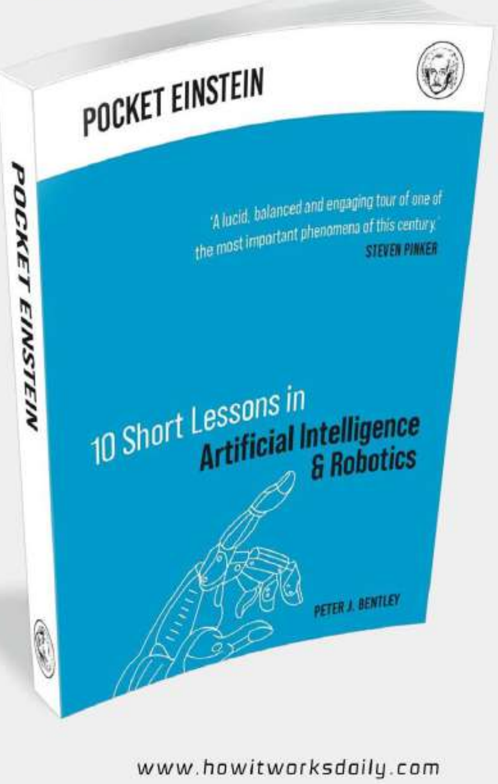
Pocket Einstein

10 short lessons in artificial intelligence and robotics

- Author: **Peter J. Bentley**
- Publisher: **Micheal O'Mara**
- Price: **£9.99 / $14.95**
- Release: **Out now**

Yet another triumph in the Pocket Einstein series, this pocket-sized deep dive into the world of AI offers exceptional insight into the robotics of the past, present and future. It's easy to get carried away when talking about what seems like the infinite possibilities of artificial intelligence, but Bentley maintains a level head when exploring the potential of AI, illustrating not only its revolutionary capabilities, but also some of its shortcomings. Bentley has constructed ten lessons that can appeal to the masses across all age groups. Whether you're a technology enthusiast looking for a well-written story of AI and robotic evolution or a novice trying to expand your knowledge on a topic that is increasingly dominating everyday life, this book is for you.

★★★★☆


POCKET EINSTEIN
'A lucid, balanced and engaging tour of one of the most important phenomena of this century.'
STEVEN PINKER
10 Short Lessons in Artificial Intelligence & Robotics
PETER J. BENTLEY

Gems

An in-depth look into the historical and scientific value of gemstones

- Author: **François Farges**
- Publisher: **Flammarion**
- Price: **£35 / $45**
- Release: **24 September**

Flicking through this almost-encyclopedic book of precious and semi-precious stones, it might appear to be a catalogue of extravagant jewellery, dripping in diamonds and inlaid with remarkable gems. However, on closer inspection the opulent photography is accompanied by insightful science about the process of the gems' formation and how they have been carved and cut throughout history to create works of art.

As a collaboration between Professor François Farges and French luxury jewellers Van Cleef & Arpels, *Gems* puts precious gemstones into perspective. Although admired for their aesthetics and rarity, this book also gives the reader an appreciation of the multi-million-year journey through extreme environmental conditions which ultimately results in their diverse and unique characteristics. This is a good coffee table book and one to refer to if you want to learn more about individual gems.

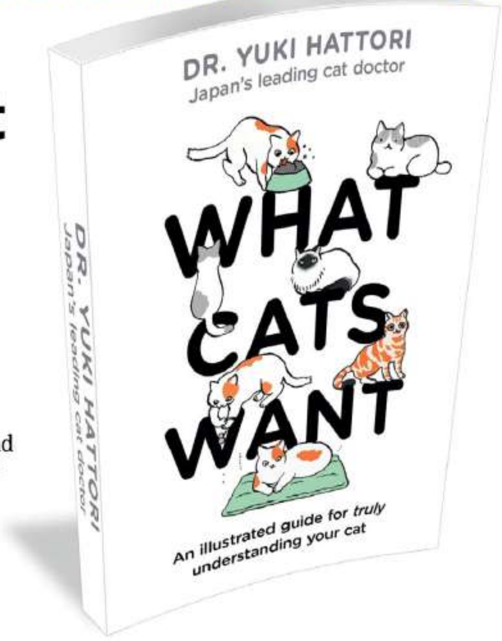
★★★★☆

Dripping in diamonds and inlaid with gems

What Cats Want

All you need to know about your feline friends

- Author: **Dr Yuki Hattori**
- Publisher: **Bloomsbury Publishing**
- Price: **£12.99 / $20**
- Release: **Out now**

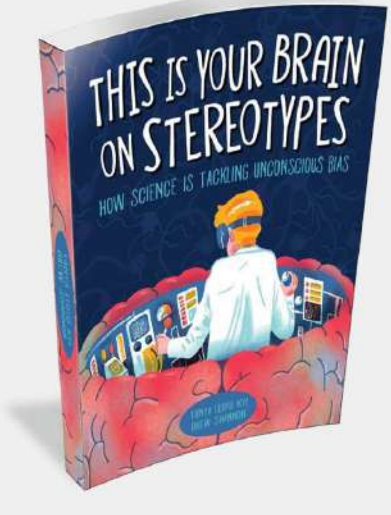

DR. YUKI HATTORI
Japan's leading cat doctor
WHAT CATS WANT
An illustrated guide for truly understanding your cat
DR. YUKI HATTORI
Japan's leading cat doctor

Have you ever found yourself looking at a cat and wondering what is going through their head? If the answer is 'yes', then here you will find the information you need. From their body language to the pitch of their meows – and every action in between – this book is essential for any cat lover looking to break the animal-human barrier.

Hattori is a specialist in feline behaviour, and his expert knowledge – combined with adorable illustrations – provides an invaluable visual guide to your cat. Filled with tips, tricks and facts, Hattori dissects the feline world for all to understand.

Most pet owners want what is best for their furry friends. But whether you are striving to provide the optimum life for your cat by knowing when they are unwell, unhappy or content or you just want to broaden your general knowledge of the animal, this book will go above and beyond your questions. Like any relationship, a level of understanding can build happiness and trust, and this book is a great tool to enhance this between you and your cat.

★★★★★


THIS IS YOUR BRAIN ON STEREOTYPES
HOW SCIENCE IS TACKLING UNCONSCIOUS BIAS

This is Your Brain on Stereotypes

The science behind unconscious bias

- Author: **Tanya Lloyd Kyi**
- Publisher: **Kids Can Press**
- Price: **£14.99 / $16.99**
- Release: **Out now**

The world needs diversity, but how are we programmed to respond to these differences? Our brains are constantly sorting and labelling objects based on their features, but when it comes to people, this process is much more complicated. Unconscious bias is instilled in us, starting when we are young, and this book has arrived at a vital time to prove and prevent its damage. How can we change the automatic perceptions we have about ourselves and others?

Using hard-hitting lessons from past events and scientific research, this book explores how we can rewire our minds to make humankind fairer. Appropriately tackling sensitive issues, this is the ideal first step for creating awareness among young people while also explaining the science behind how this works. The carefully chosen illustrations brighten each page, while the narrative is written to help understand terms like 'bias', 'stereotype' and 'prejudice' by using simple analogies. Drawing challenges and other activities keep the reader actively engaged to see how easily stereotypes can be held and what they might have picked up from society.

★★★★☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 In the Western Pacific hurricanes are known as:
- ○ Cyclones
- ○ Typhoons
- ○ Beauforts
- ○ Gusts

Q2 How many arms do octopuses have?
- ○ 4
- ○ 6
- ○ 8
- ○ 12

Q3 Which of these video game consoles was launched first?
- ○ Microsoft Xbox
- ○ Sony PlayStation
- ○ Nintendo 64
- ○ Sega Genesis

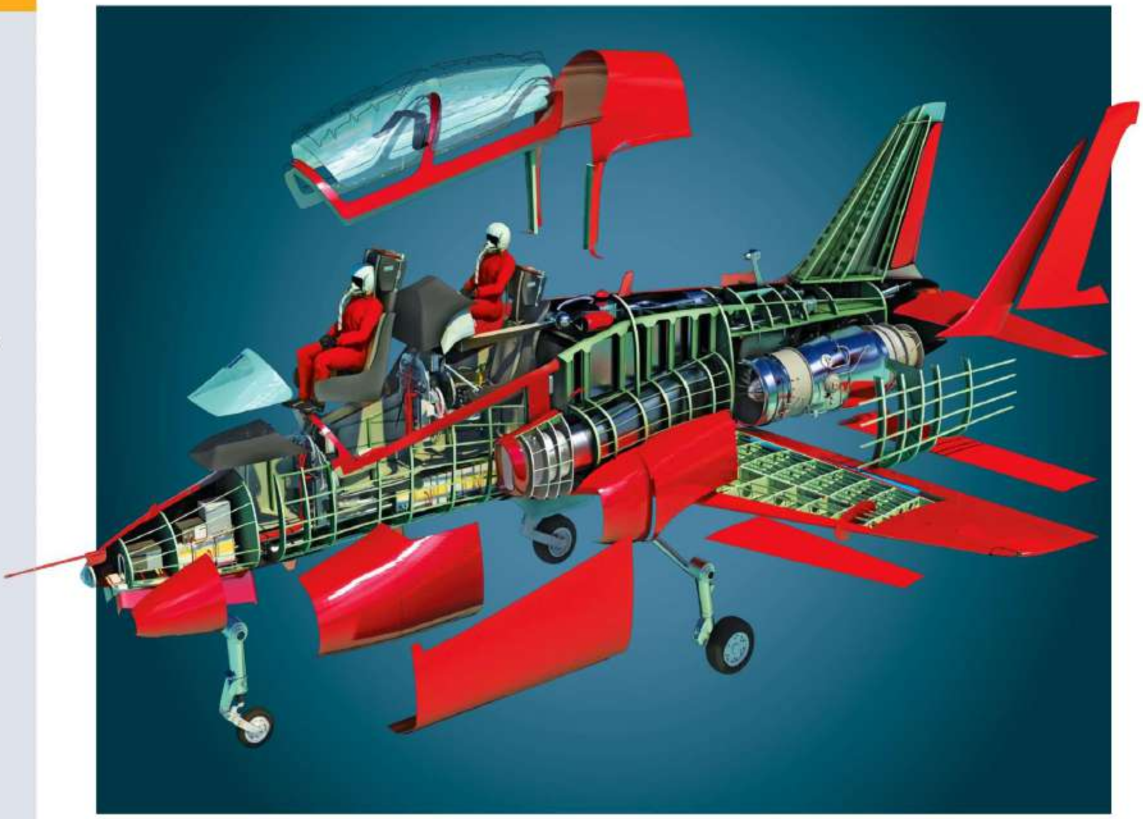
Q4 When was the first motorway built?
- ○ 234 BCE
- ○ 1896
- ○ 1924
- ○ 1958

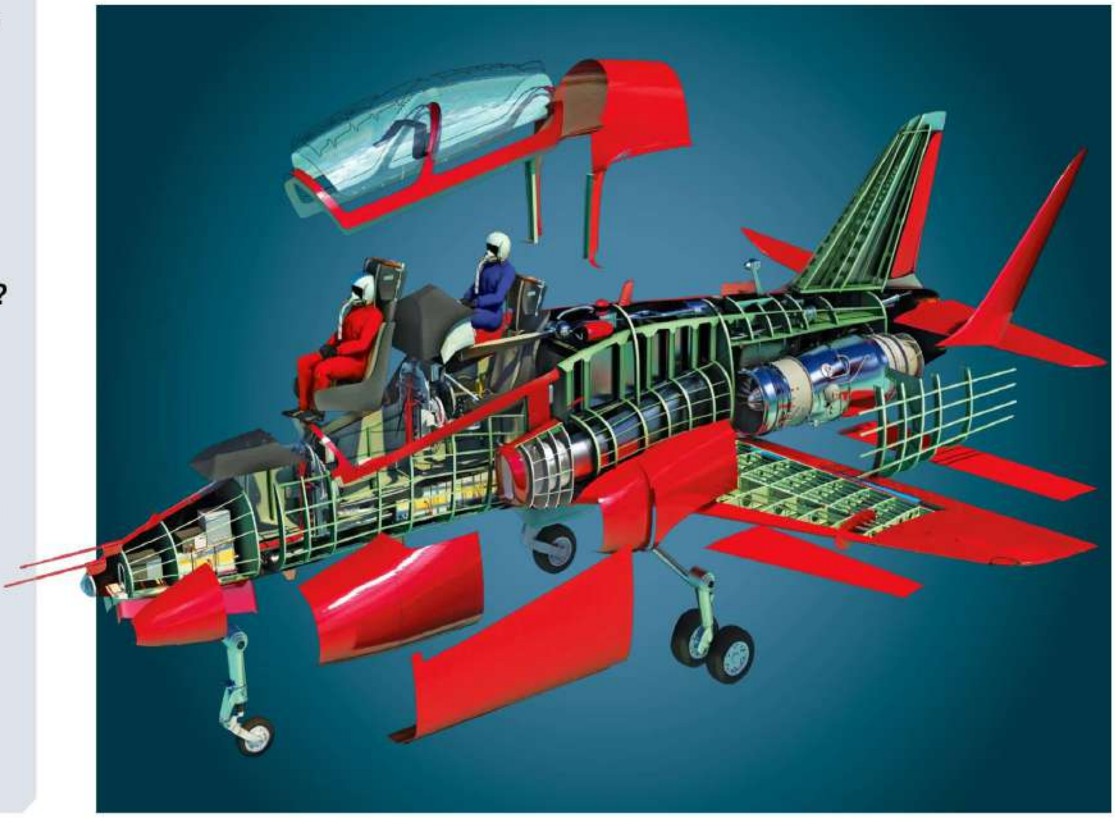
Q5 Which element turns molten glass red?
- ○ Cobalt
- ○ Selenium
- ○ Gold
- ○ Carbon

Q6 What happened to Ariel 1, the UK's first satellite, in 1962?
- ○ It was hit by an asteroid
- ○ The US nuked it
- ○ It flew into the Sun
- ○ Russia captured it

Spot the difference

See if you can find all six changes between the images below





Sudoku

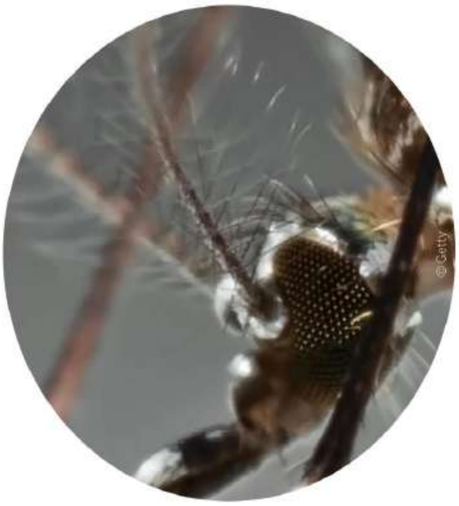
Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		7		4		8		
			8					
	5			9	7	6	3	
6	3		2	7		1		8
	8		5	3	6	7	2	4
7			9		8			
		6	7		3			
5		4	6	2	9	3	8	7
3	7	9			1			

DIFFICULT

				9	8	5		
		2	6	1		9		
			2				4	8
				7		1		
			3			8		5
4	9	6						
			4		5	2		
							5	
		1	8		9	7		


© Getty

What is it?

Hint: This annoying bug 'hears' with these feathery antennae...

A ....

H	U	R	N	I	P	O	R	E	N	I	C	E	R	E
O	E	L	E	C	T	R	I	C	T	L	V	U	Q	I
C	A	H	G	A	N	I	T	S	G	N	I	M	A	G
P	M	U	M	M	Y	N	D	O	L	A	C	R	U	H
J	O	R	M	U	W	T	U	D	O	R	P	A	B	T
K	C	R	C	O	A	L	I	G	H	E	Z	I	R	V
O	N	I	Y	J	T	J	U	R	R	E	F	C	A	O
P	I	C	O	U	R	P	O	U	H	C	A	N	I	R
W	F	A	E	N	M	N	H	C	R	T	O	E	L	E
S	C	N	Q	K	U	C	H	E	O	T	S	C	I	L
S	J	E	L	R	U	E	Y	D	A	O	H	X	O	Y
A	T	G	M	O	R	A	O	A	D	E	M	O	J	A
L	Y	N	P	A	X	R	U	I	A	P	M	E	T	E
G	E	I	L	T	R	O	P	I	C	A	L	P	O	P
E	L	A	S	I	R	E	P	O	R	T	C	E	L	E

Wordsearch

FIND THE FOLLOWING WORDS...

HURRICANE
TROPICAL
POUCH
EIGHT

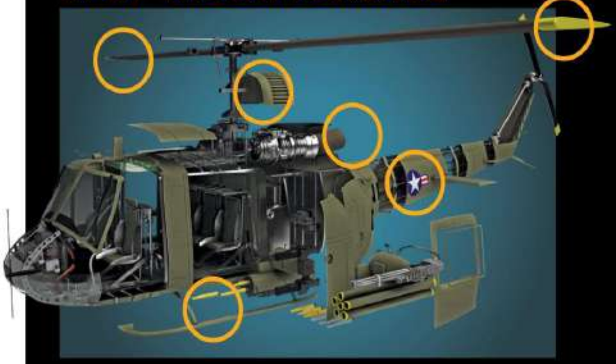
GAMING
COCOA
ELECTRIC
MUMMY

TUDOR
GLASS
JUNK
ROAD

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 A fizzy drink can full

Q2 0 metres a second

Q3 Sputnik

Q4 60

Q5 Emperor penguin

Q6 1,075kg

WHAT IS IT? ...MARS

© NASA

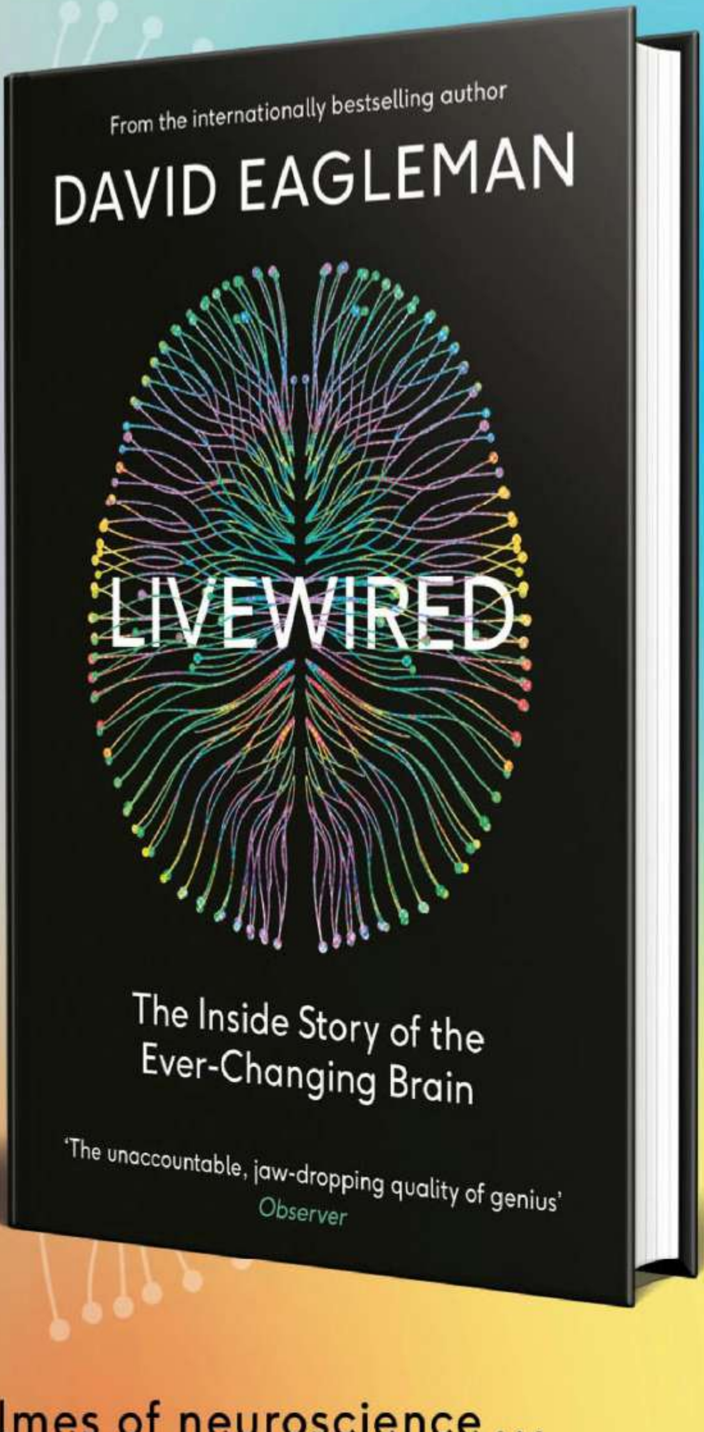
LIFT THE LID ON THE MOST POWERFUL TECHNOLOGY YOU'LL EVER USE:

THE HUMAN BRAIN

What does drug withdrawal have in common with a broken heart?

How can a blind person learn to see with her tongue?

What does how we dream have to do with the rotation of the planet?


From the internationally bestselling author
DAVID EAGLEMAN
LIVEWIRED
The Inside Story of the Ever-Changing Brain
'The unaccountable, jaw-dropping quality of genius'
Observer

'The jolly Sherlock Holmes of neuroscience ... His knowledge and enthusiasm are intoxicating'
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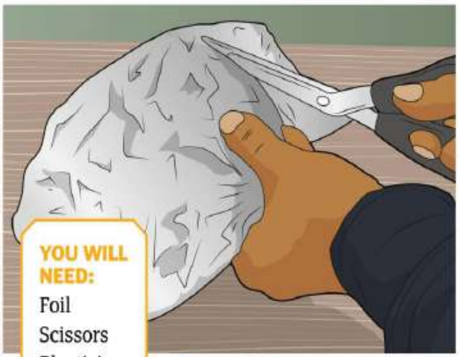
How to make a tea light turbine

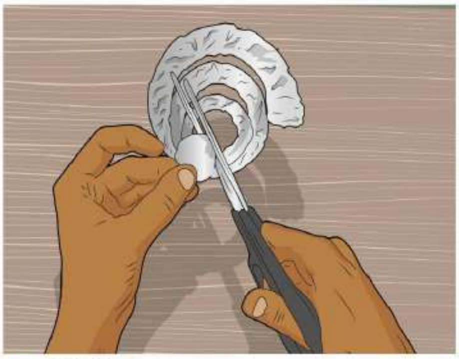
Watch your turbine spin using the power of a single flame



YOU WILL NEED:
- Foil
- Scissors
- Plasticine
- A skewer
- A tea light
- Lighter or matches

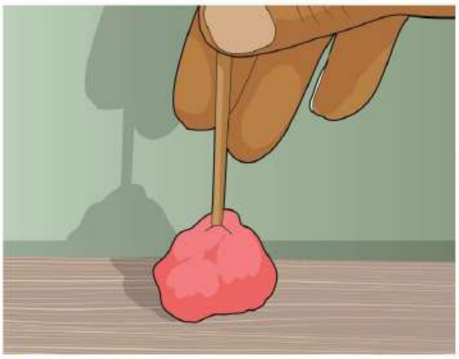
1 Cut a circle

Taking your scissors and foil, carefully cut out an even circle, filling the width of the foil.



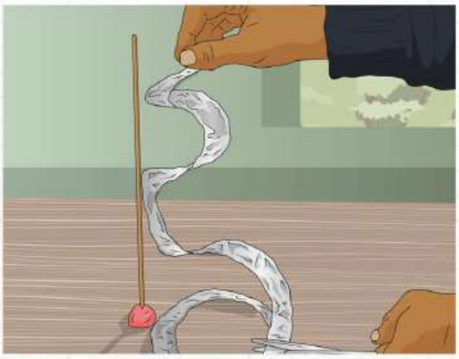
2 Spiral out

Starting at the edge of the circle, cut the foil into a spiral. Keep the scissors about two-and-a-half centimetres from the outside edge as you cut around towards the middle.



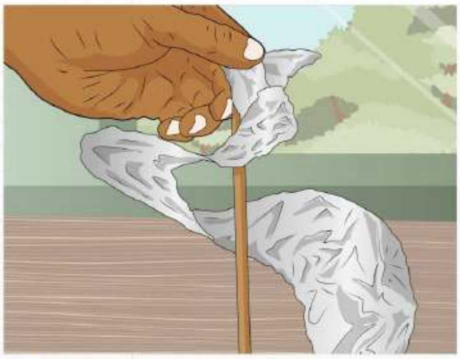
3 Make the stand

Stick a small handful of plasticine onto a flat surface and place your skewer vertically into it with the pointed end facing upwards – this will form the base for your spiral.



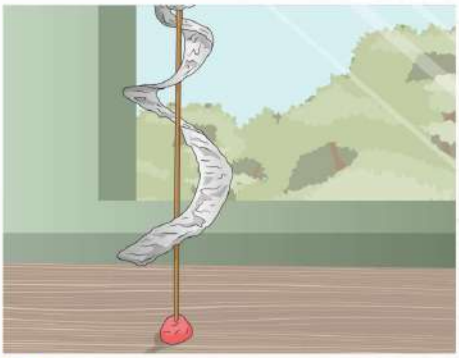
4 Adjust the spiral

Hold the foil spiral's centre at the top of the skewer and cut the bottom so its length is roughly the same length as the skewer.



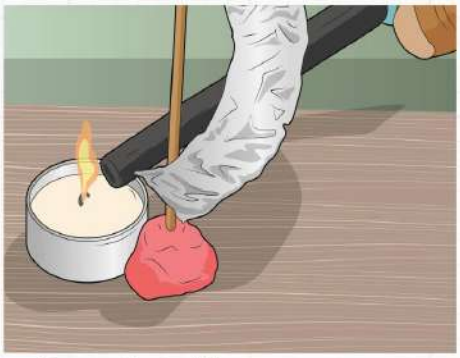
5 Pinch the top

Place the centre of the spiral over the pointed end of the skewer and pinch the foil so that it clings onto the top.



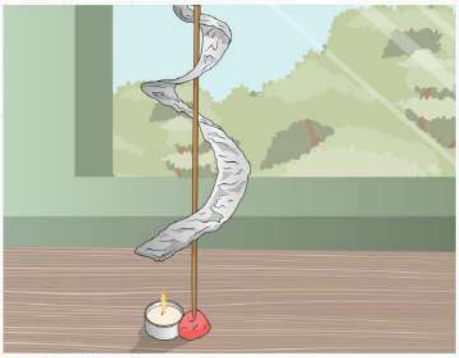
6 Final adjustments

Wrap the spiral around the skewer and re-cut its length so that the end hangs about five centimetres above the table.



7 Power the turbine

Place a tea light next to the plasticine and carefully light it up with a lighter or match. Watch to see how quickly the foil begins to move. If it doesn't, loosen the top slightly.



8 Turbine in motion

Observe the turbine as it turns around the skewer and glistens in the candlelight, pushed into motion by the flame's rising heat in a process called convection.

SUMMARY

This experiment works due to convection. When the tea light is lit, the flame heats the surrounding air particles, causing them to lose density and rise above the cooler air. As the particles rise they push against the foil, creating the movement. When building your turbine, make sure the foil is balanced securely but is still able to move freely.

Had a go? Let us know!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE
How to make a cloud in a jar

© Illustrations by Ed Crooks

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INBOX

Speak your mind...

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag

howitworks@futurenet.com

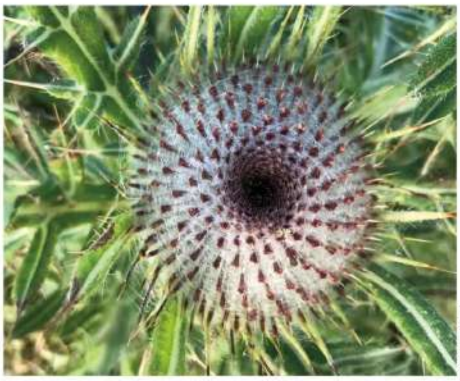
CROWN
OF
CROWNS
CLARA LOVEMAN

© Ingram Spark

WIN!

A COPY OF CROWN OF CROWNS

Pharmaceutical scientist Clara Loveman's debut young-adult fiction novel combines science fiction and romance as two lovers from different backgrounds fight against the system for their lives and for the freedom of all.



© Anne Marl

This sequence and its presence in nature has fascinated scientists for centuries

Fibonacci thistle

Dear **HIW,**

On a walk I passed this thistle plant and noticed this beautiful and intricate pattern. When looking at the photograph, it got me thinking about the Fibonacci sequence. I don't know much about it, but wondered if you could tell me if it's connected to this pattern?

Anne Marl

What a mesmerising picture, and a great choice to demonstrate the Fibonacci sequence. The Fibonacci sequence is a series of numbers where each is the sum of the two that came before it: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55.... This sequence can often be found in the structure of natural things. Your photograph is a perfect example of this, where you can see the concentric spiral pattern. This is a genetically determined pattern, and the resulting spirals match up with the numbers in the sequence. These spirals can be found on all thistles, pinecones and some flower heads. Next time you see the spiral on a snail or the number of branches growing from a tree, see if you can spot where these numbers hide.

Letter of the month

Seeking immunity

Dear **HIW,**

This is a question I have been pondering for a while. How do vaccines work? What do they put in your body and how do they know where to put them?

Zack

These are incredibly topical questions, with scientists around the world currently aiming to produce a new life-saving vaccine. It's the job of white blood cells to respond to an infection when it enters the body, recognising danger and acting quickly to eliminate it before it does any further damage. Before they can carry out this vital role, your immune system needs to build familiarity with each infection. Vaccinations prepare the body for a more efficient response by exposing the immune system to a weaker version of an infection.

If you are exposed to the same virus or infection again, the body will recognise it and the specific cells needed to kill it will be created. Vaccines contain weakened or dead germs combined with a substance which helps to kick-start the process, called an adjuvant. Vaccines are usually injected deep into your muscles, where the contents can be absorbed efficiently into the bloodstream.

When vaccines are being tested, the most effective methods are discovered and spread to other scientists. Once the most effective entrance into the body is found, the bloodstream will carry the cells throughout the body, and you build up your defences.

Countries are currently racing to create a vaccine for COVID-19

© Pixabay / Angelo Esslinger

Ocean currents are constantly moving and always changing

© Pixabay / Markus Steinacher

Battling the currents

Hi **HIW,**

I have started swimming now that the sea is warmer. As I swam out to sea and back again, I noticed that one way was quicker than the other, notably due to the current. The next day this direction changed, and I assumed it was because of the wind blowing in one direction. However, after more swimming on calm days, the direction of the current still changes. What causes these changes?

Erin Mcginty

The more you encounter the sea, the more you will become aware of its ever-changing character. Its current is one of the elements that often changes, and the surprising strength can be very dangerous if you are unaware of its movements. You are right in suspecting that the wind impacts these movements. Global winds are a major cause as they move the water to create surface currents. However, this is not the only factor in the currents' speed and direction, and the wind alone won't always tell you the sea's conditions.

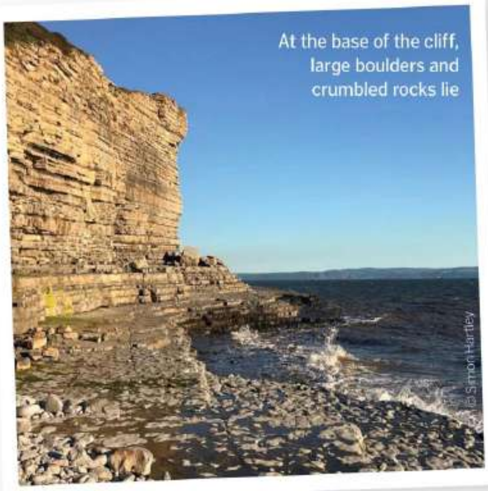
Temperature as well as salt fluctuations at sea can bring on a surge in current. When the sea water becomes more or less dense it rises and sinks, impacting the movement of surrounding water. Cold water or salty water is more dense, and as it moves down, water will be pushed up from below and stir up your swim.

Cliff caution

Dear **HIW,**

After studying the geography of coastal erosion, it has made me take closer notice of the cliffs and their structures. Erosion at the cliff base in this picture I have taken has caused precarious overhanging rock at the top, and the debris at the bottom could then be used as ammunition to erode the cliff further. I wondered how likely it is to be caught by these falling rocks. Do they fall regularly and is there any way of knowing when the area is dangerous?

Simon Hartley


At the base of the cliff, large boulders and crumbled rocks lie

© Simon Hartley

Thank you for sending us your picture of this dramatic cliff face. In the UK it's common for cliffs to erode between one and two metres each year. As erosion at the bottom makes the top unstable, it is next to impossible to know when the rock is going to give way. It is best to steer clear of the bottom of these cliffs. Different rock types can erode quicker than others, while stormier regions can batter the land much more violently than in other areas. It is fascinating to watch the result of the wind and sea's force, but it is best not to spend a long time near this rocky debris.

COMING SOON!

ASK US HOW IT WORKS

DO YOU HAVE A CURIOUS QUESTION YOU NEED THE ANSWER TO?

Maybe you always find yourself wondering how, what and why?

Every Thursday we will answer as many of your questions as possible, live on Twitter.

To take part, simply tweet your question on the day using the hashtag **#askHIW**

What's happening on...

social media?

This month on Instagram we asked you what you think the coolest natural phenomenon is

@_rchiesw_in
Definitely the northern lights. The night sky looks so cool full of colours.

@scimaxfacts
Volcanic lightning because it is really cool!

@hamid.baghernia
Sunrise and sunset, beautiful result of the Sun, atmosphere and Earth's rotation

@zidaneyvt4
Undersea mountain, it's a beautiful scene when it's explosion time

@maia_h3
Thermal springs - natural heated pools!

@aestheically_aj : Sun halos because they look magical

@cameronharvey : Rogue waves! They're so dramatic and powerful

NEXT ISSUE...

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FAST FACTS

Amazing trivia to blow your mind

180kph

THE POLAR JET STREAM WINDS, OVER NINE KILOMETRES ABOVE SEA LEVEL, CAN BLOW AT SPEEDS GREATER THAN A CATEGORY 3 HURRICANE

20,000

THERE ARE THOUSANDS OF NEAR-EARTH ASTEROIDS KNOWN TO ASTRONOMERS, AND MANY MORE UNKNOWN

1962

SPACEWAR! WAS THE WORLD'S FIRST COMPUTER GAME, DEVELOPED AT MIT

65KPH

WINGSUIT JUMPERS CAN EASILY SLOW THEIR DESCENT TO LESS THAN HALF THE SPEED OF SKYDIVERS

15

MORE THAN A DOZEN DIFFERENT ELECTRIC SOCKET STANDARDS ARE USED WORLDWIDE

THE DARKER THE CHOCOLATE, THE MORE HEALTHY ANTIOXIDANTS AND NUTRIENTS IT CONTAINS

LIBYAN DESERT GLASS FORMED WHEN A METEOR EXPLODED ABOVE THE DESERT 29 MILLION YEARS AGO

262,280 MILES

THE UK'S ROAD NETWORK COULD STRETCH AROUND THE WORLD OVER TEN TIMES

7020 BCE

CHILE'S CHINCHORRO MUMMIES ARE EVEN OLDER THAN EGYPT'S

97%

VIKING 1 AND 2 MAPPED ALMOST ALL OF MARS' SURFACE FROM ORBIT

DOCTORS NEED MORE ANAESTHETIC TO PUT SMOKERS TO SLEEP THAN NON-SMOKERS

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HISTORY OF THE BRITISH FIGHTER SPITFIRE MK VB

A single-seat, single-engine all-metal monoplane fighter. After the Mk II and two more experimental variants of the Spitfire, the next major variant to see mass production was the Spitfire Mk V. Central to this new Spitfire was its engine – the 1470 HP Rolls Royce Merlin 45. This was equipped with a single stage supercharger and, coupled with a new carburettor design, allowed the Mk V to perform zero G manoeuvres without starving the fuel flow to the engine; a problem which had plagued earlier models of the Spitfire.

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